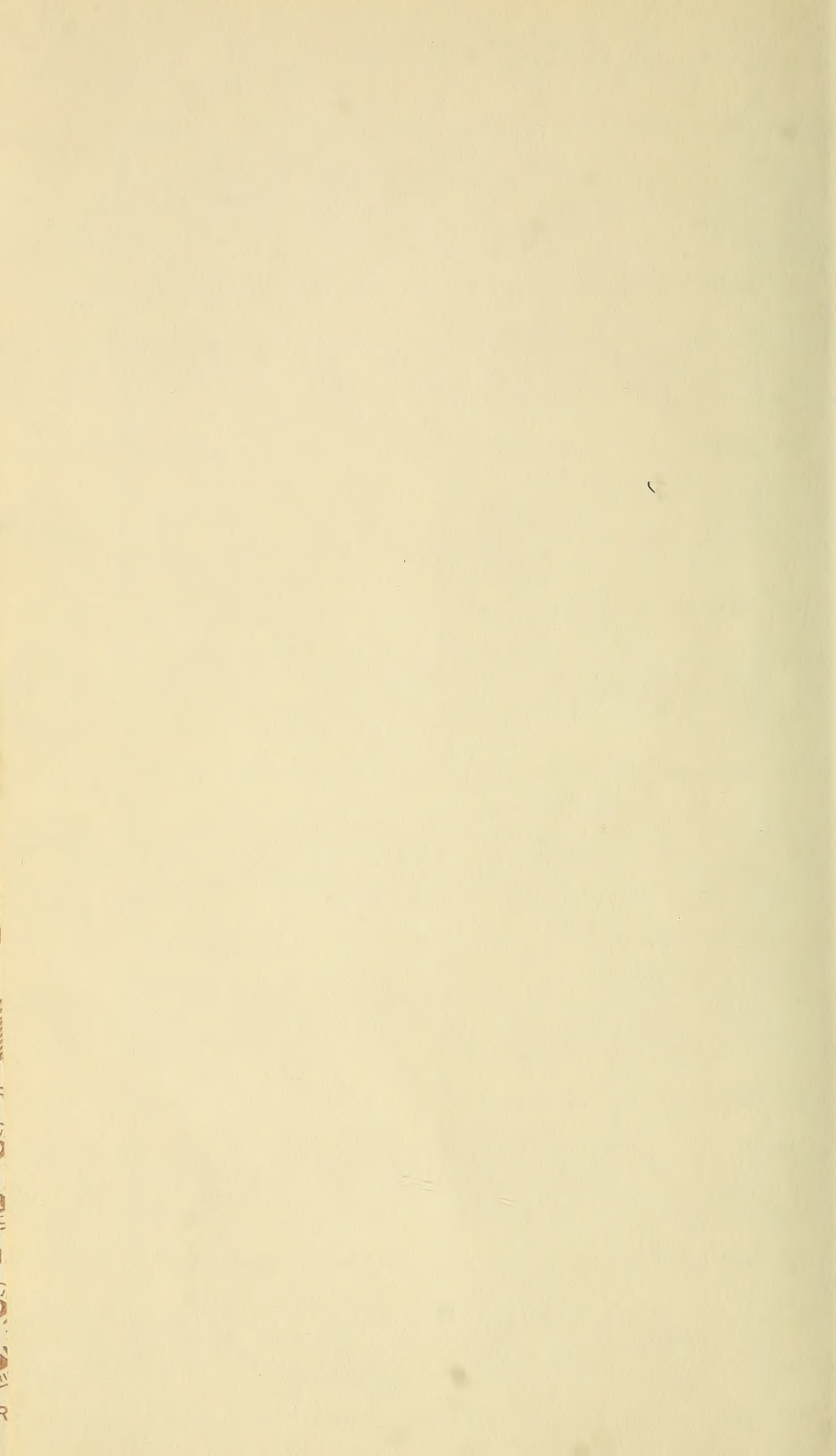










New York State Museum

FREDERICK J. H. MERRILL Director

Bulletin 58

MINERALOGY 2

GUIDE TO THE

MINERALOGIC COLLECTIONS

OF THE

NEW YORK STATE MUSEUM

BY

HERBERT P. WHITLOCK C.E. 1892

BUREAU OF
AMERICAN ETHNOLOGY.

Cancelled
1892
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Bulletin 58

MINERALOGY 2

GUIDE TO THE MINERALOGIC COLLECTIONS

OF THE
NEW YORK STATE MUSEUM

PREFACE

The kindly reception given to the *Guide to the Study of the Geological Collections of the New York State Museum*, published in 1898, and the evidences of its utility as a teachers' aid in the schools of the state, have made it seem desirable to continue this method of treatment in regard to the other branches illustrated in the New York State Museum.

Mr Whitlock, assistant in mineralogy, has accordingly, prepared for publication the following bulletin and it is offered to the citizens of the State of New York in the hope that it will meet a material want and aid many teachers in their instructional work in mineralogy by supplementing the textbooks now available.

FREDERICK J. H. MERRILL

Albany N. Y. July 14, 1902

Director

PART I

GENERAL PROPERTIES OF MINERALS

INTRODUCTORY DEFINITIONS

The science of mineralogy embraces a knowledge of all natural inorganic substances of definite chemical composition which go to make up the crust of the earth, and, so far as our knowledge extends, of other solid bodies in the universe.

Minerals, in the sense adopted in the following pages and generally in science, constitute only a part of the mineral kingdom. A mineral must be a homogeneous substance, that is, it must be of the same nature throughout. Many rocks which seem to the unaided eye to be composed of a single substance are shown by more careful examination under the microscope to be made up of more than one substance. A mineral must also have a definite chemical composition as expressed by a chemical formula. Thus, obsidian, or volcanic glass, though frequently quite homogeneous, is not classed as a mineral owing to its lack of definite composition.

Again, it is customary to exclude from the list of mineral species all substances which have not been formed by the processes of nature and such mineral substances as have been directly produced by organic life. Under this head are excluded laboratory and furnace products such as the carbonate of lime produced by passing carbon dioxid through limewater, which is not a mineral species though it has the same composition as the mineral calcite or natural carbonate of lime. Phosphate rock is not classed as a mineral owing to its organic origin though it has essentially the same composition as the mineral apatite which is the natural phosphate of lime.

The rocks which compose the earth's crust are either single minerals, such as marble, a massive form of calcite, or aggregates of two or more minerals. An example of the latter case is granite, composed of three or more separate and distinct minerals which may readily be recognized as different: a glassy mineral showing rough surfaces along the fracture, which is

called quartz; a white, pink or salmon colored mineral which shows on the fracture a series of smooth surfaces and which is called a feldspar; and a black fibrous mineral which is known as hornblende.

Crystallization

When a substance in the condition of a liquid or a gas becomes solid it is often seen that this solid has a regular outline, smooth, bright sides or faces and sharp angles. This results from the fact that the particles or molecules of the substance, which while it was liquid or gaseous rolled about on one another, have been in some way arranged, grouped and built up. To illustrate this, suppose a quantity of small shot to be poured into a glass, the shot will represent the molecules of a substance in

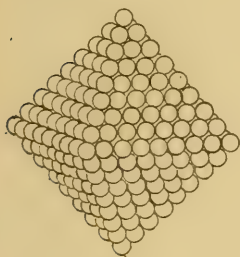


Fig. 1

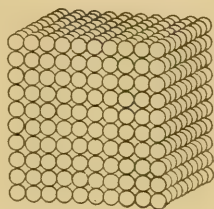


Fig. 2

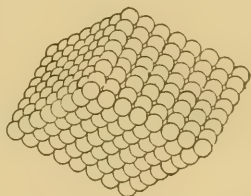


Fig. 3

the liquid state, as for example a solution of alum. If, now, we suppose these same shot to be coated with varnish or glue so that they will adhere to each other and imagine them grouped as shown in fig. 1 they will represent the arrangement of the molecules of the alum after it has become solid or crystallized. This arranging, grouping and piling up of the molecules is called crystallization and the solid formed in this way is called a crystal. Fig. 2 and 3 show the shot arranged to reproduce two common forms of crystals.

There are many common examples of crystallization. The snowflakes, which are formed by the cooling of watery vapor in the air, are composed of small crystals which are quite apparent to the eye and are often of great beauty and regularity of form. The same may be said of the frost which forms on a window

pane. The formation of crystals may be reproduced in a very striking manner; take for example a strong solution of salt and set it aside in a shallow dish over night; after the water has evaporated the bottom of the dish will be found covered with small cubic crystals of salt. The forces of nature working much more slowly but in a similar way have produced the vast deposits of native salt or halite which sometimes yield very large crystals.

Crystal masses

When a number of crystals are formed in a limited space the individual crystals intersect and lap over one another producing what is known as crystal masses. If this intersecting is carried to such an extent as to entirely fill the bounded space, leaving no interstices between the crystals, the mineral is said to be massive. The term massive in its broader sense includes mineral masses which do not show definite crystal faces but which in most cases can be shown to be distinctly crystalline by means of cleavage and optical properties. Experiment and study of mineral deposits show that a liquid substance which is cooled slowly or a solution which is concentrated gradually tends to form large and perfect crystals while substances which are solidified rapidly produce small and ill defined crystals, often giving rise to massive forms. A substance which displays no evidences of crystallization is said to be amorphous as distinct from crystalline. Glass is a good example of an amorphous substance.

Laws of crystals

A complete study of all known forms of crystallized substances has shown that the formation of crystals is subject to the following laws:

- 1 Law of constancy of interfacial angles
- 2 Law of symmetry
- 3 Law of simple mathematical ratio

Law of constancy of interfacial angles

In all crystals of the same substance the angle between any two like faces is constant. Fig. 4 and 7 show two crystals of

the mineral zircon, both being composed of the faces marked *p* and *m*. An examination of fig. 5, 6, 8 and 9,

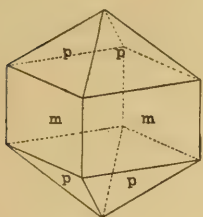


Fig. 4

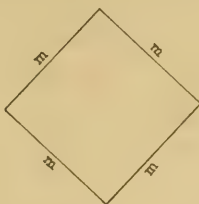


Fig. 5

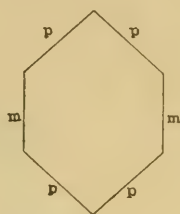


Fig. 6

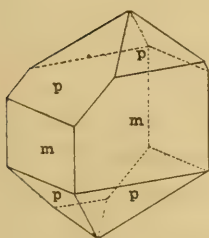


Fig. 7

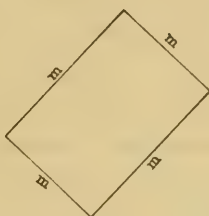


Fig. 8

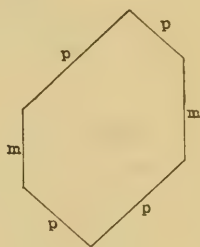


Fig. 9

which show sections through fig. 4 and 7, will demonstrate that the angles between *m* and *m* in fig. 5 and 8 are equal as are also the angles between *p* and *p* and between *p* and *m* in fig. 6 and 9. Compare the cardboard model 6¹, which shows the same crystal as fig. 4. Fig. 10 shows a distorted octahedron of magnetite, the shaded form within the outline representing the normal octahedron equally developed in all directions; the faces of the outer and inner forms are parallel each to each. The cardboard model 1 is an ideal octahedron.

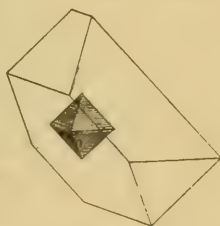


Fig. 10

Law of symmetry

By symmetry is meant the degree of regularity with which the faces and angles of a crystal are grouped about points, lines and planes. Thus a crystal may be symmetric to a plane, symmetric to a line or axis, symmetric to a point or center.

¹The cardboard models will be found in a pocket attached to the cover.

A crystal is symmetric to a plane when it may be so divided by that plane that every face, edge and angle on the one side is repeated on the opposite side. In fig. 11, which represents a crystal of pyroxene, the shaded space shows the intersection

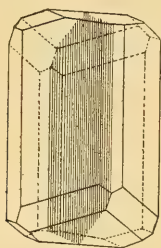


Fig. 11



Fig. 12

of the crystal by a plane of symmetry, and it will be observed that the portion of the crystal lying to the right of the plane is related to the portion lying on the left in the same way that the reflected or mirrored image of the half crystal is related to the direct image. Fig. 12 shows fig. 11 as seen from above.

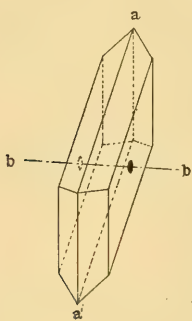
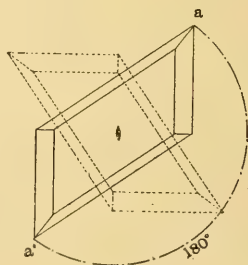


Fig. 13



A crystal is said to be symmetric to an axis of binary symmetry when it occupies the same position in space twice during one revolution about the axis, the coinciding positions being 180° apart. A consideration of fig. 13 and 14 will make this clearer; in fig. 13 *b* is an axis of binary symmetry and if the crystal is revolved as shown in fig. 14 the point *a* will have to traverse an arc of 180° and coincide with *a'* before the crystal

will occupy the same position in space. An axis of binary symmetry is indicated by this sign .

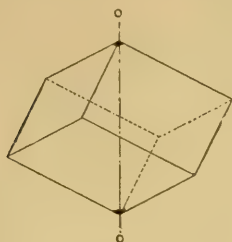


Fig. 15

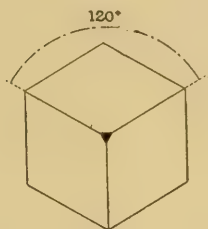


Fig. 16

Similarly a crystal is said to be symmetric to an axis of trigonal symmetry when it occupies the same position in space

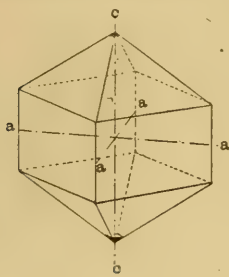


Fig. 17

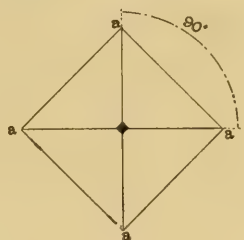


Fig. 18

three times during one revolution about the axis, the coinciding positions being 120° apart. Fig. 15 and 16 show a crystal of

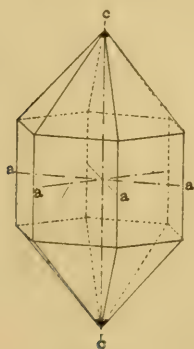


Fig. 19

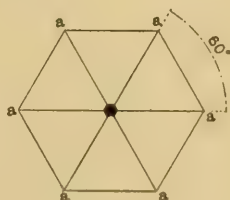


Fig. 20

calcite, $c-c$ being an axis of trigonal symmetry, indicated by the sign . Compare model 7.

A crystal is symmetric to an axis of tetragonal symmetry when it occupies the same position in space four times during one revolution about the axis, the coinciding positions being 90° apart. Fig. 17 and 18 show a crystal of zircon, $c-c$ being an axis of tetragonal symmetry indicated by the sign $\blacklozenge$.

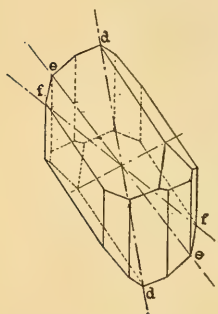


Fig. 21

Hexagonal symmetry is shown when a crystal occupies the same position in space six times during one complete revolution about the axis of symmetry, the coinciding positions being 60° apart. Fig. 19 and 20 show a crystal of quartz, $c-c$ being an axis of hexagonal symmetry indicated by the sign $\blacklozenge$.

A crystal is symmetric to a point or center when every imaginary straight line passing through that point intersects the crystal at its two extremities in similar faces, edges or solid angles. This is the least symmetric of all the conditions so far discussed and is illustrated by the crystal of chalcantite or blue vitriol shown in fig. 21.

Crystallographic axes

The relations between the faces of a crystal are best studied by assuming certain directions within the crystal called axes. Such axes may, in the more symmetric groups, be axes of symmetry, and when the crystal is symmetric to one or more planes of symmetry, they bear a definite relation to those planes.¹ Three (in one system four) such axes are chosen, their relative inclination and lengths forming a basis for classifying all crystals into six systems.

If the symmetry of a crystal permits the grouping of faces around one axis to be identical with the grouping of faces around another, the two axes are said to be interchangeable. In fig. 17 and 18 the axes marked a are interchangeable but

¹ In the normal groups of the isometric, tetragonal, hexagonal and orthorhombic systems, the axes are found at the intersection of the planes of symmetry, and in the normal group of the monoclinic system two axes lie in the plane of symmetry and a third is perpendicular to it.

a and c are not interchangeable. The same statement holds good for fig. 19 and 20. Cardboard models 6 and 7 will help to make this clear. Fig. 16, 18 and 20 show that if one crystallographic axis is also an axis of trigonal, tetragonal or hexagonal symmetry the other crystallographic axes will be at right angles to it and interchangeable.

Crystal form

When every face of a crystal cuts the axes to which it is referred at the same relative distances from the center or inter-

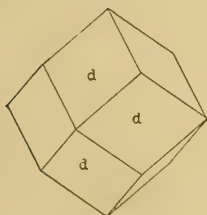


Fig. 22

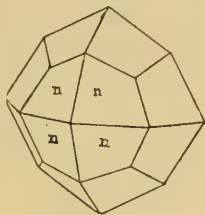


Fig. 23

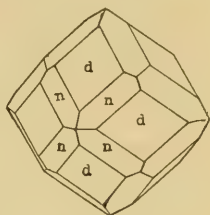


Fig. 24

section of the axes, the crystal is said to be composed of a single crystal form. Two such crystals are shown in fig. 22 and 23 from which it will be noticed that all the faces of each crystal form are similar. Compare models 1, 2, 3, 4 and 5, all of which are crystal forms. Crystals may be composed of a single crystal form or of combinations of two or more forms. Such a combination is shown in fig. 24 which is made up of the two forms shown in fig. 22 and 23.

Law of simple mathematical ratio

If the faces of a crystal are extended to intersect the axes it will be found that these points of intersection lie at the ratio distance a , b , and c characteristic of the substance, or at distances which are simple multiples or fractions of these ratio distances. Should a plane be parallel to one or two of the axes its intercepts, or in other words the relative distances from the center at which it cuts these axes, are infinity. Assuming the

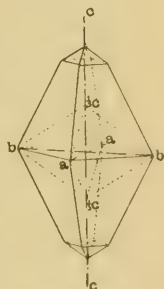


Fig. 25

axes *a-a*, *b-b* and *c-c* (fig. 25) of the ratio or unit lengths of sulfur, that is to say,

$$a-a: b-b: c-c: = 0.813: 1: 1.903$$

possible crystal faces of sulfur might have intercepts

$$a: b: c: = .813: 1: 1.903$$

$$3a: b: c: = 3(.813): 1: 1.903$$

$$a: b: \frac{1}{3}c: = .813: 1: \frac{1}{3}(1.903)$$

$$\infty: b: c: = \infty: 1: 1.903 \text{ etc.}$$

The quantities by which the ratio distances of any substance must be multiplied to give the intercepts for any ordinary crystal form of that substance are infinity and such simple numbers as 1, 2, 3, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{3}{2}$, etc. Fig. 25 shows the crystal resulting from the combination of the crystal forms *a:b:c* and *a: b: $\frac{1}{3}c$* of sulfur.¹

Systems of crystallization

Crystals of all known forms, however varied and complicated, may be classified under the following six systems of crystallization, which will be taken up in detail.

1 Isometric

4 Orthorhombic

2 Tetragonal

5 Monoclinic

3 Hexagonal

6 Triclinic

¹Instruments employed for the measurement of interfacial angles are known as goniometers and are represented by two types: 1) contact goniometers which measure on a graduated half circle the angle obtained by directly applying to the faces of the crystal two pivoted arms; 2) reflection goniometers which operate on the principle of reflection from the brilliant crystal faces of the image of a point of light. The crystal is attached to a rotating graduated circle on which the required angle is read. Of the two types the latter is by far the more accurate particularly for small crystals.

The polarizing microscope, which is extensively used in determining the optical properties of minerals and in the study of rocks, differs from the ordinary microscope in three essential features.

1 It is equipped with a revolving stage centered in the axis of the microscope and graduated on the circumference.

2 Below the stage is inserted a device which polarizes the light that passes from the reflector, that is to say only those rays of light that vibrate parallel to a certain plane are transmitted.

3 Above the stage is placed a similar polarizing device called the analyzer which transmits the light that vibrates in planes perpendicular to the plane of the lower polarizer.

These two polarizing devices, known as nicols prisms or "nicols," are constructed from cleavage rhombohedrons of transparent calcite and are so arranged that they are readily inserted or removed.

Isometric system

Crystals included in the isometric system can be referred to three interchangeable axes at right angles to each other.¹ The molecular structure of the mineral with respect to these axes is revealed not only by the outward form of the crystal but by the property, common to all isometric minerals, of transmitting polarized light equally in all directions. By virtue of this property a thin section of an isometric mineral cut in any direction will remain dark when viewed in a polarizing microscope between crossed nicols or when observed in a similar way in the tourmalin tongs. There are five groups, differing slightly in symmetry, included in the isometric system, three of which contain nearly all the isometric minerals known.

Any mineral of which definite crystals are found produces forms which show the symmetry of a distinct group, and *it is impossible to find in nature a crystal whose symmetry would place it in more than one group.*

Normal group



Fig. 26

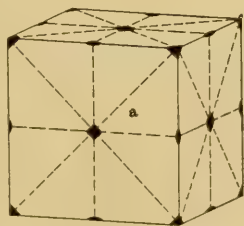


Fig. 27

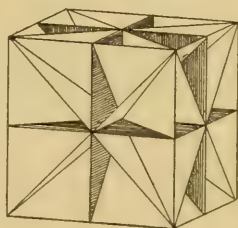


Fig. 28

The general symmetry of this group is shown in fig. 26 and 27. The crystallographic axes are axes of tetragonal symmetry and any form belonging to the group, as for example the cube shown in fig. 27, must be symmetric to the planes which inter-

¹ In the ideal representation of an isometric crystal these axes are equal. Such a condition, however, seldom occurs in nature, the crystal being distorted in various directions. In the following brief outline, as well as in the description of mineral species, the diagrams represent ideal crystals and the reader's attention is directed to the symmetry and distribution of the faces shown, which are invariable however much the actual crystal may be distorted.

sect, as shown in fig. 28. The shaded planes of fig. 28 intersect in axes of tetragonal symmetry, the white planes intersect in axes of trigonal symmetry.

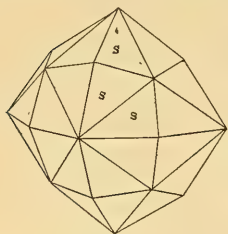


Fig. 29

Hexoctahedron. The hexoctahedron (fig. 29) is composed of 48 faces, each cutting the three axes at relatively different distances. The faces, which are scalene triangles, are grouped around the trigonal axes in groups of six.

Cube. The cube (fig. 27, model 2) is composed of six square faces each of which is parallel to two axes. This crystal form is represented by a number of minerals, the most common being galena, fluorite, halite, etc.

Dodecahedron. The dodecahedron (fig. 30, model 3) is composed of 12 rhombic faces, each of which cuts two axes at the same relative distance and is parallel to the third. This crystal form is quite common in garnet, and is found to a less degree in magnetite and other minerals.

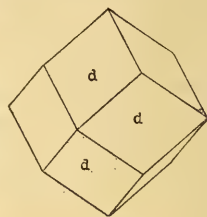


Fig. 30

Tetrahexahedron. The tetrahexahedron (fig. 31) is composed of 24 faces each of which is parallel to one axis and cuts the other two at relatively unequal distances. The faces, which are isosceles triangles, are grouped in fours about the axes of tetragonal symmetry and the long edges are parallel to the edges of a cube or hexahedron. This

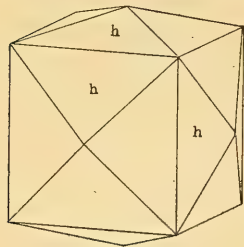


Fig. 31

crystal form, in combination, is well illustrated by copper, fluorite and other minerals.

Octahedron. The octahedron (fig. 32, model 1) is composed of eight equilateral triangular faces which cut the three axes equally. Good examples of this form may be found in crystals of magnetite and spinel.

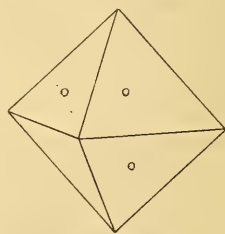


Fig. 32

Trisoctahedron. The trisoctahedron (fig. 33) is composed of 24 faces, each of which cuts two axes at equal distances and the third at a distance which is relatively greater. The faces are isosceles triangles and are disposed in groups of eight about the axes of tetragonal symmetry and in groups of three about the axes of trigonal symmetry. The trisoctahedron is occasionally found in combination with other forms as in galena.

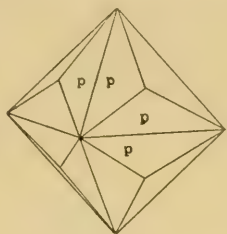


Fig. 33

Trapezohedron. The trapezohedron (fig. 34) is composed of 24 faces each of which cuts two axes at equal distances and the third at a distance which is relatively less. Garnet, leucite, analcite and other minerals crystallize in trapezohedrons.

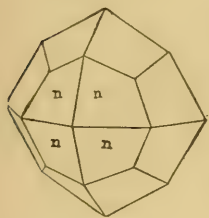


Fig. 34

Of the above named crystal forms the cube, dodecahedron and octahedron alone present an unvarying constancy of form, the cube and octahedron being identical with the familiar geometric forms. In the hexoctahedron, tetrahexahedron, trisoctahedron and trapezohedron the variations in the relative values of the axial intercepts give rise to a number of variations under

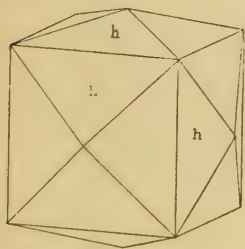


Fig. 35

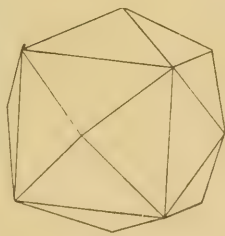


Fig. 36

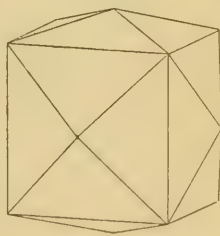


Fig. 37

each form, each subject to the law of simple mathematical ratio. The series of tetrahexahedrons shown in fig. 35-37 serves to illustrate this point. Fig. 35 and 37 are forms occurring in copper and fig. 36 is frequently observed on crystals of fluorite.

Some of the combinations of forms in this group are given in fig. 38-43, the lettering of the faces being the same as that used for the corresponding simple forms.

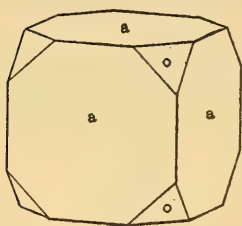


Fig. 38

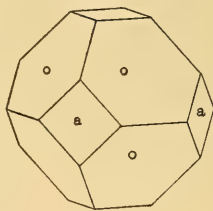


Fig. 39

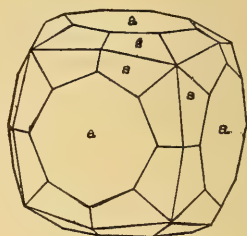


Fig. 40

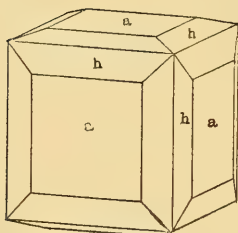


Fig. 41

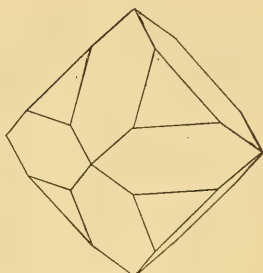


Fig. 42

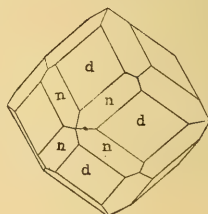


Fig. 43

Pyritohedral group

The general symmetry of the pyritohedral group is shown in fig. 44. The crystallographic axes are axes of binary symmetry

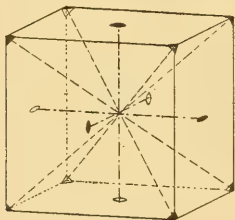


Fig. 44

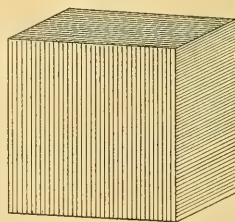


Fig. 45

and forms of this group are symmetric only to the shaded planes of fig. 28. The cube, octahedron, dodecahedron, trisoctahedron and trapezohedron, which occur in this as well as in the preceding group, are here distinguished by striations, natural etching and modifying faces which clearly show their binary symmetry; as for example the cube of pyrite shown in fig. 45, which occurs striated in the directions of the alternate parallel edges of each square face.

Pyritohedron. The pyritohedron (fig. 46, 47, model 4) is named from the species pyrite, of which it is a characteristic form.

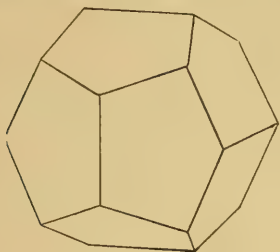


Fig. 46

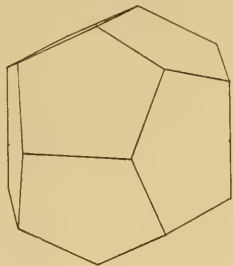


Fig. 47

It is composed of 12 pentagonal faces, each of which is parallel to one axis and meets the other two at unequal distances. As will be seen from fig. 46 and 47 the pyritohedron exists in complementary forms, fig. 46 being known as the *plus* and fig. 47 as the *minus* form. The 24 faces of the plus and minus pyritohedrons have the same position in space as the 24 faces of the corresponding tetrahexahedron of the normal group.

Diploid. The diploid (fig. 48, 49) is composed of 24 quadrilat-

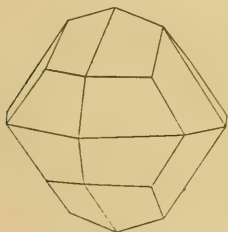


Fig. 48

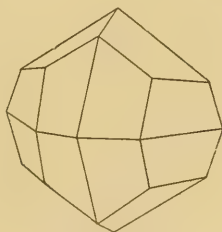


Fig. 49

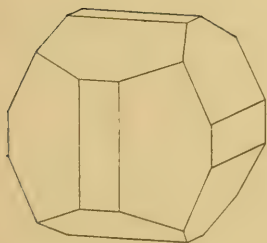


Fig. 50

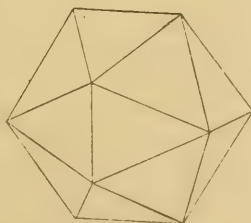


Fig. 51

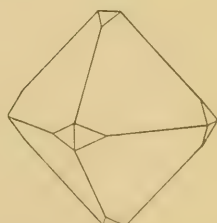


Fig. 52

eral faces each of which meets the axes at unequal distances. The complementary plus (fig. 48) and minus (fig. 49) forms bear the same relation to the hexoctahedron of the normal group

as the plus and minus pyritohedrons do to the tetrahexahedron. Fig. 50-52 show combinations of forms in this group and represent crystals of pyrite and cobaltite.

Tetrahedral group

The general symmetry of this group is shown in fig. 53. The crystallographic axes are axes of binary symmetry and the crystals of this type are symmetric to the six white planes of fig. 28. The cube, dodecahedron and tetrahexahedron occur in this group but are readily distinguished from the same forms of the normal type by the degree of symmetry shown in their combinations with other forms. The axes of trigonal symmetry indicated in fig. 53 constitute a characteristic feature of the group.

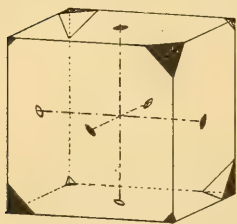


Fig. 53

Tetrahedron. The tetrahedron (fig. 54, 55, model 5) is composed of four equilateral triangular faces each of which meets

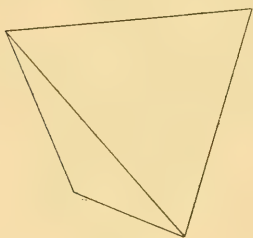


Fig. 54

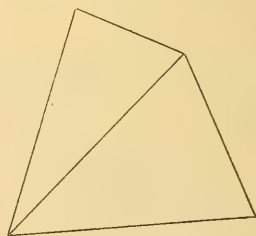


Fig. 55

the axes at equal distances. Two tetrahedrons are possible and are known as plus (fig. 54) and minus (fig. 55), the eight faces composing them corresponding to the eight like faces of the octahedron.

Trigonal tristetrahedron. The trigonal tristetrahedron (fig. 56, 57) is composed of 12 triangular faces each of which meets two axes at equal distances and the third at a distance which is relatively less than the intercept on the other two. A plus trigonal tristetrahedron is shown in fig. 56 and the corresponding minus form in fig. 57; these bear a relation to the trapezo-

hedron of the normal group similar to that of the tetrahedron to the octahedron.

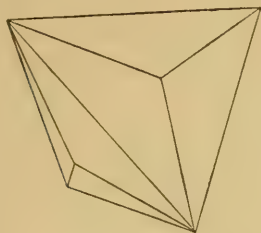


Fig. 56

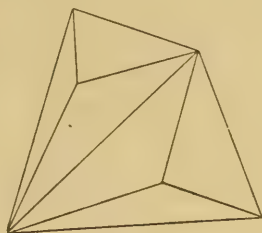


Fig. 57

Two other forms, the tetragonal tristetrahedron (fig. 58) and the hexakistetrahedron (fig. 59) are occasionally found in combination. Some combinations in this group are shown in fig. 60-65.

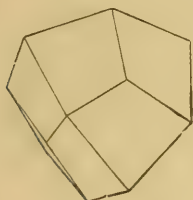


Fig. 58

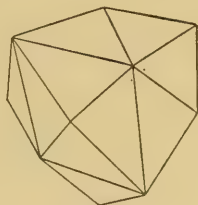


Fig. 59

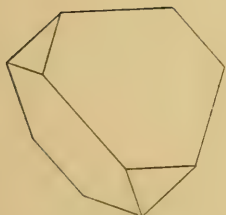


Fig. 60

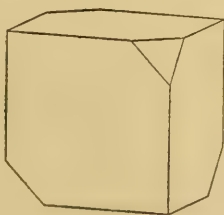


Fig. 61

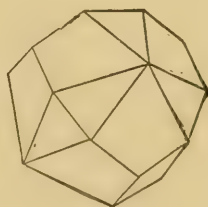


Fig. 62

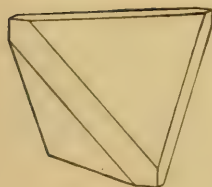


Fig. 63

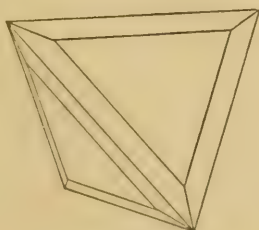


Fig. 64

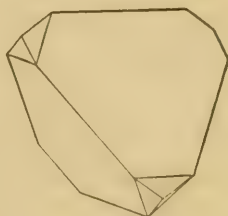


Fig. 65

Tetragonal system

Crystals in the tetragonal system can be referred to three axes, all at right angles to one another, two of which are equal and interchangeable (denoted in fig. 66 by a) and the third (c) is at right angles to the plane of the other two and is of a different length (greater or less) from the a axes.

The relative lengths of the a and the c axes vary in each tetragonal species, though there are several instances where this ratio differs to such a small degree in several species as to warrant placing them together in what is known as an isomorphous group.¹

Normal group

The general symmetry of this group is shown in fig. 66. The vertical axis c is an axis of tetragonal symmetry and the hori-

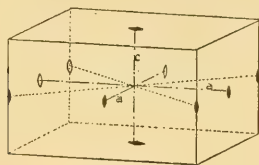


Fig. 66

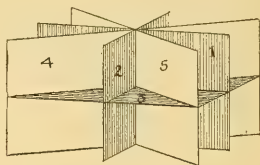


Fig. 67

zontal axes $a a$ are axes of binary symmetry. There are moreover two axes of binary symmetry which bisect the angles between the axes $a a$. Any form in the group is symmetric to the planes shown in fig. 67. Compare model 6.

Pyramids. A form composed of planes which intersect the horizontal axes $a a$ at equal distances and which also intersect the vertical axis c is known as a pyramid of the first order and is composed of eight isosceles triangular faces. When the intercept on c as compared with that on a gives the axial ratio for any species the form is said to be the unit pyramid for that species. Fig. 68 shows the unit pyramid of zircon, the value of c for zircon being .64. Fig. 69 shows the unit pyramid of octahedrite where $c=1.777$.

¹ See p. 45.

For each tetragonal species there may be several pyramids of the first order intersecting the vertical axis at multiples or

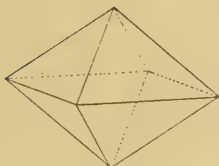


Fig. 68



Fig. 69

fractions of the unit length c and producing steeper or flatter forms than the unit pyramid.

The pyramid of the second order is composed of eight isosceles triangles each of which is parallel to one horizontal axis a and intersects the second horizontal axis a and the vertical axis c .

The second order pyramid of zircon is shown in fig. 70.

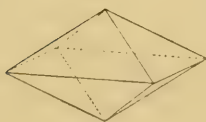


Fig. 70



Fig. 71

The ditetragonal pyramid (fig. 71) is composed of 16 isosceles triangular faces intersecting the horizontal axes at unequal distances and also intersecting the vertical axis.

Prisms. For each type of pyramid in the normal group there is a corresponding prism having the same relative intercepts on the horizontal axes as the pyramids of the same name, and having every face parallel to the vertical axis. These prisms are denoted as follows:

Prism of the first order, having four faces, represented in fig. 72 by the faces marked m .

Prism of the second order, having four faces, represented in fig. 73 by the faces marked *a*.



Fig. 72

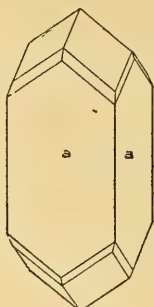


Fig. 73

Ditetragonal prism, having eight faces.

The basal plane or base consists of a pair of planes parallel to the horizontal or basal axes.

The symmetry of this group can be best observed by considering what is called the termination of the crystal, that is, the

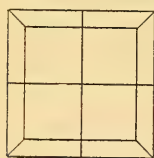


Fig. 74

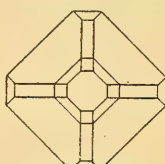


Fig. 75

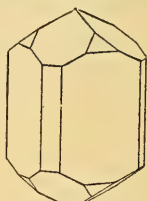


Fig. 76

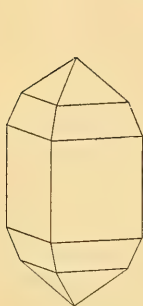


Fig. 77



Fig. 78

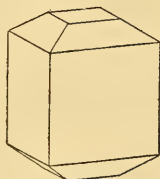


Fig. 79

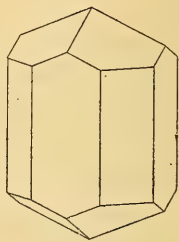


Fig. 80

way in which the planes are grouped about the extremity of the vertical axis; two such terminations are shown in plan in fig. 74 and 75. Some of the combinations in the normal group are shown in fig. 72-80.

Pyramidal group

The general symmetry of this group is shown in fig. 81; as in the normal group the vertical axis is an axis of tetragonal symmetry; a single plane of symmetry passes through the horizontal axes, which are not axes of binary symmetry as is the case in the normal group.



Fig. 81

The forms which have been described under the normal group occur also in the pyramidal group with the exception of the ditetragonal prism and pyramid.



Fig. 82

The relation between the symmetry of this group and that of the preceding one may be best studied by referring to fig. 82 which shows the termination of a pyramidal crystal. The absence of vertical planes of symmetry, characteristic of this group should be noted.

Two new forms occur, namely: prism of the third order, represented in fig. 84; pyramid of the third order, represented in fig. 83 by the faces marked *x*.

The relations of the pyramid and prism of the third order

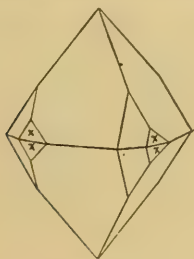


Fig. 83

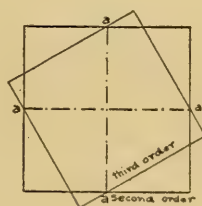


Fig. 84

to the corresponding forms of the first and second order are shown in fig. 84. Fig. 83 represents some combinations in this group.

Sphenoidal group

The general symmetry of this group, which is shown in fig. 85, is somewhat analogous to that of the tetrahedral group of the isometric system. The crystallographic axes are axes of

binary symmetry and there are moreover, two vertical planes of symmetry (fig. 67, no. 4, 5).

This symmetry admits of two new forms.

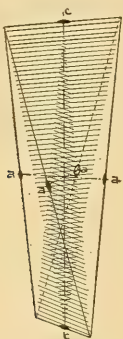


Fig. 85



Fig. 86

1 The tetragonal sphenoid (fig. 85, 86) is composed of four isosceles triangles which meet the horizontal axes at equal distances; they also intersect the vertical axis. Two sphenoids are possible which include all the faces of the pyramid of the first order of the normal group. The form is analogous to the tetrahedron of the isometric system.

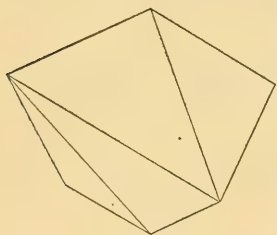


Fig. 87

2 The tetragonal scalenohedron (fig. 87) is composed of eight scalene triangles, which intersect the horizontal axes unequally. As with the sphenoid there are two complementary scalenohedrons possible for every different ratio of the intercepts on the horizontal axes. Up to the present

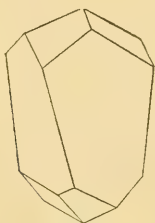


Fig. 88

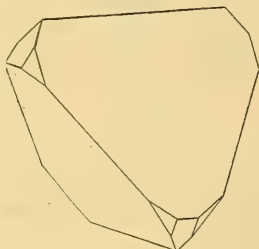


Fig. 89

time the scalenohedron has been found only in combination with other crystal forms of this group.

Some of the combinations in this group are shown in fig. 88 and 89, which illustrate crystals of chalcopyrite.

Hexagonal system

There are in general many points of resemblance between hexagonal crystals and those which are included in the tetragonal system. This analogy is accentuated by the fact that the molecular structure of the minerals in both systems as exhibited in their optical properties show striking similarity. Hexagonal as well as tetragonal crystals are said to be optically uniaxial; that is, in every crystal of these two systems a section cut normal to the vertical axis will remain dark when viewed between crossed nicols in the polarizing microscope; any other section will show an interference color which changes to darkness or "extinction" at regular intervals as the stage of the microscope is rotated.

Hexagonal crystals are referred to four crystallographic axes, one of which is vertical and perpendicular to the plane of the other three; this vertical axis, as in the tetragonal system, is indicated by *c*. The three horizontal axes are interchangeable and at 60° from each other; they are indicated by *a*.

*A Hexagonal division***Normal group**

The general symmetry of this group is shown in fig. 90 and 91. The vertical axis is an axis of hexagonal symmetry and each

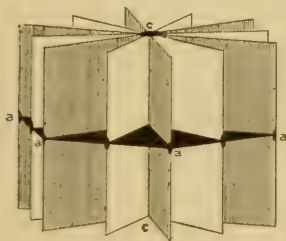


Fig. 90

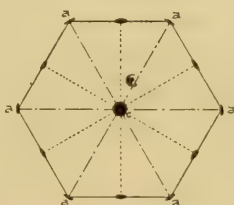


Fig. 91

basal axis is an axis of binary symmetry; there are also three axes of binary symmetry bisecting the angles between the crystallographic axes. Crystals in this group are symmetric to a plane of symmetry through the basal axes and to six planes of symmetry passing through the vertical axis and each of the axes of binary symmetry. The nomenclature of the forms is analogous with that used in the normal group of the tetragonal system, the forms being briefly stated as follows:

PYRAMIDS

Pyramid of the first order

FIG.

92

Pyramid of the second order

93

Dihexagonal pyramid

94

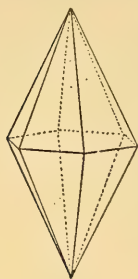


Fig. 92

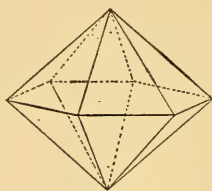


Fig. 93

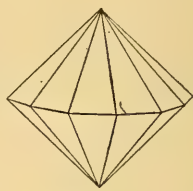


Fig. 94

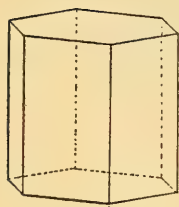


Fig. 95

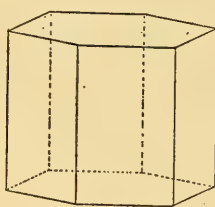


Fig. 96

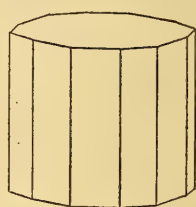


Fig. 97

PRISMS

Prism of the first order

FIG.

95

Prism of the second order

96

Dihexagonal prism

97

The basal pinacoid is shown terminating the prisms in fig. 95-97. The relation of these forms to one another is shown in fig.

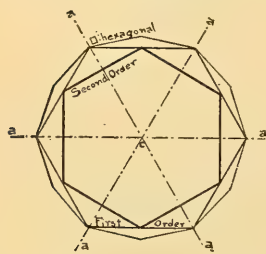


Fig. 98

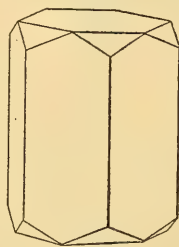


Fig. 99



Fig. 100

98. Two combinations in the normal group are shown in fig. 99 and 100, which represent crystals of beryl.

Pyramidal group

The symmetry of this group resembles that of the pyramidal group of the tetragonal system in that crystals of this type are symmetric to the horizontal plane of symmetry shown in fig. 90. The vertical axis (*c*) is an axis of hexagonal symmetry. Fig. 101 gives an idea of the general arrangement of faces about

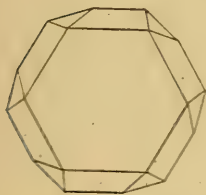


Fig. 101

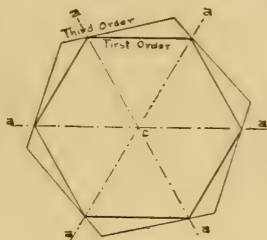


Fig. 102

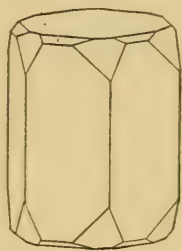


Fig. 103

this axis. The third order pyramid and prism, indicated in plan in fig. 102, are of frequent occurrence in this group, as well as the pyramids and prisms of the first and second order described above.

The crystal of vanadinite shown in fig. 103 illustrates a combination of pyramidal forms. Apatite and pyromorphite are common minerals in this group.

B Rhombohedral division

The groups which come under this division differ from the hexagonal forms hitherto discussed in the essential feature of a vertical axis of trigonal symmetry which gives to the termination of rhombohedral crystals a trigonal as distinct from a hexagonal aspect. Compare fig. 104, which shows a termination of a rhombohedral crystal, with the hexagonal terminations shown in fig. 91 and 101. Compare also model 8 with model 7.



Fig. 104

Rhombohedral group

Forms in this group are characterized by a vertical axis of trigonal symmetry and three horizontal axes of binary symmetry, these axes being identical with the crystallographic axes. They are also symmetric to three planes which intersect in the vertical axis as shown in fig. 105.

Rhombohedron. The rhombohedron (fig. 106, 107, model 8) is composed of six rhombic faces, each of which intersects two basal axes at equal distances, is parallel to the third and cuts the vertical axis (c). The two rhombohedrons possible for every relative value of the vertical intercept are complementary plus (fig. 106) and minus (fig. 107); the 12 faces of the plus and minus rhombohedrons include all the faces of a hexagonal pyramid of the first order having the same relative intercepts. Some rhombohedrons of calcite of varying vertical intercepts are shown in fig. 107-9.

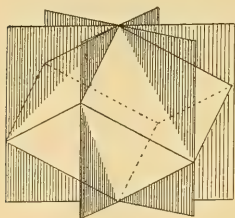


Fig. 105

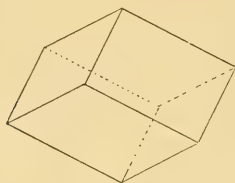


Fig. 106

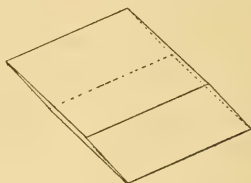


Fig. 107



Fig. 108

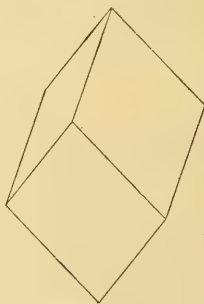


Fig. 109

Scalenohedron. The scalenohedron (fig. 110) is composed of 12 scalene triangular faces each of which cuts all four axes. As with the rhombohedron two forms are possible for every value of the vertical intercept. These are related to the dihexagonal pyramid in the same way that the rhombohedron is related to the pyramid of the first order.

The remaining forms of the rhombohedral group are geometrically the same as the corresponding forms of the normal group and are: prism of the first order; prism of the second order; pyramid of the second order; basal plane.

Some of the combinations in this group are shown in fig. 111-13.

Rhombohedral-hemimorphic group

Comparing this group with the preceding one, the main points of difference to be noted are the lack of symmetry to a point, which is characteristic of hemimorphic crystals, the two extremities of the vertical axis showing dissimilar modifications, and the fact which results from the above, namely, that the horizontal

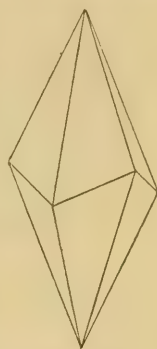


Fig. 110

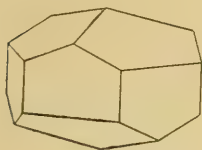


Fig. 111

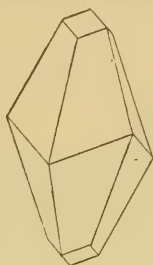


Fig. 112



Fig. 113

axes are no longer axes of binary symmetry. A crystal of tourmalin, which is an important species of this type, is shown in fig. 114 and serves to illustrate the main features of the group.

Trirhombohedral group

Trirhombohedral crystals are characterized by the absence of planes of symmetry; they are, however, symmetric to a point.

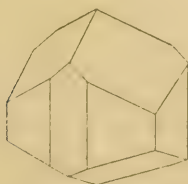


Fig. 114



Fig. 115

The vertical axis is an axis of trigonal symmetry. The minerals ilmenite, dolomite, phenacite, diopside and willemite occur in forms of this group. Fig. 115 shows a crystal of ilmenite.

Trapezohedral group

The forms in this group possess the lowest grade of symmetry in the hexagonal system, having no plane of symmetry and no center of symmetry; the vertical axis is, however, an axis of trigonal symmetry and the three horizontal axes (a) are axes of binary symmetry.

Trapezohedron. The trigonal trapezohedron (fig. 116, 117) is a characteristic form of this group and consists of six trapezohe-

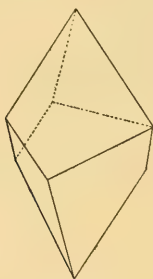


Fig. 116

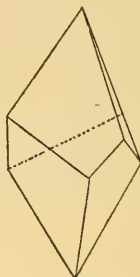


Fig. 117

dral faces each of which cuts all the axes. Four trapezohedrons are possible; two plus, called respectively right-handed (fig. 116) and left-handed (fig. 117), and two minus forms which are also

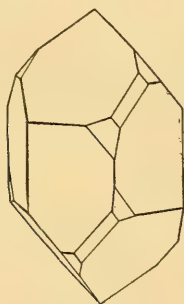


Fig. 119

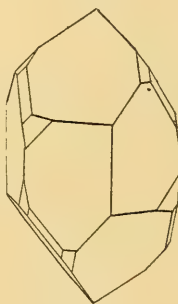


Fig. 120

right-handed and left-handed. The 24 faces of these four forms constitute the planes of a dihexagonal pyramid.

The two crystals of quartz shown in fig. 119, 120 show the trigonal trapezohedron in combination with other forms of the group; they are termed respectively right-handed and left-handed forms.

Trigonal pyramid. The trigonal pyramid (fig. 118) consists of six triangular faces, each of which cuts two basal axes (a) at equal distances and the third at a distance which is relatively half as great, each face also intersects the vertical axis.

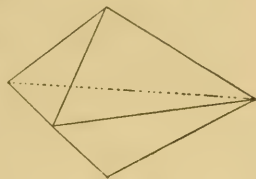


Fig. 118

Orthorhombic system

Crystal forms included in the orthorhombic system are referred to three unequal uninterchangeable axes at right angles to one another. These axes are shown in fig. 121; the shorter horizontal one, called the brachyaxis, is designated by a , the longer horizontal axis, called the macroaxis, by b and the vertical axis by c . The relative position of the macro and brachy

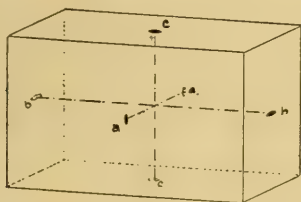


Fig. 121

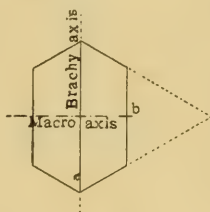


Fig. 122

axes in a crystal of any orthorhombic species is determined by the intercepts of a face occurring in that species, called a unit plane. The unit plane is selected from among those which cut both a and b axes and is preferably a plane which intersects all three axes. The intercepts of the a and c axes in terms of b constitute the axial ratio, which is a constant for each orthorhombic species. Difficulty is sometimes experienced in properly orienting an orthorhombic crystal owing to the fact that the crystal is often flattened in the direction of the macroaxis; thus in fig. 122, which shows a crystal of cerussite in plan, the brachyaxis *appears* to be longer than the macro because the crystal is elongated in the direction of a .

Normal group

Forms of the normal group are symmetric to three planes of symmetry intersecting in the crystallographic axes, which are axes of binary symmetry (fig. 123).

Pinacoids. Planes which are parallel to two orthorhombic axes are known as pinacoids; they consist of two parallel planes and take their names from the axes to which they are parallel, thus:

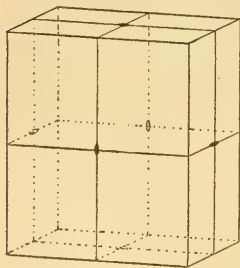


Fig. 123

The basal pinacoid is parallel to both basal axes a and b .

The macropinacoid is parallel to the macro and the vertical axis.

The brachypinacoid is parallel to the brachy and the vertical axis.

Fig. 123 shows the intersection of these three pinacoids, the resulting solid being analogous to the cube of the isometric system and the second order prism and base of the tetragonal system.

Prisms. Prisms cut both horizontal axes, and are parallel to the vertical axis; they are composed of four faces, opposite pairs being parallel. The unit prism for any species intersects the basal axes at relative distances which give the axial ratio for that species. In fig. 124, which shows a basal section of the mineral topaz, such a unit prism is indicated, the axial ratio for topaz being $a:b=.529:1$.

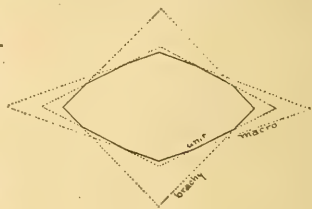


Fig. 124

Prisms occur intersecting the basal axes at distances proportionately more or less than the axial ratio subject to the law of

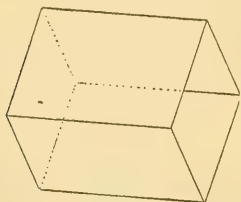


Fig. 125

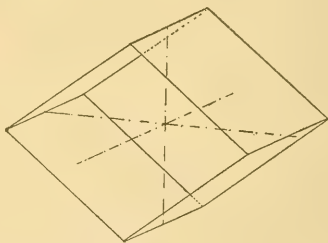


Fig. 126

rational indexes. These are called respectively macro or brachy prisms according as they are more nearly parallel to the macro or brachy axis than the unit prism. A macro and a brachy prism are shown in fig. 124.

Domes. Domes may be considered horizontal prisms; they are parallel to one horizontal axis and cut the other horizontal axis and the vertical axis. Like the pinacoids they take their names from the axes to which they are parallel thus:

The macrodome (fig. 125) is parallel to the macroaxis and cuts the brachy and the vertical axes.

The brachydome (fig. 126) is parallel to the brachyaxis and cuts the macro and the vertical axes.

Macrodomes and brachydomes are often repeated in series, the relative value of the vertical intercepts being subject to the law of rational indexes.

Pyramids. The single type of pyramid found in this system is shown in fig. 127 and is composed of eight faces each cutting all three axes. The unit pyramid for any species intersects the axes at distances corresponding to the axial ratio for the species.

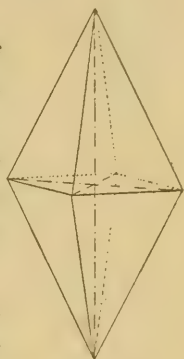


Fig. 127

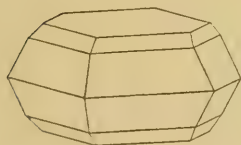


Fig. 128

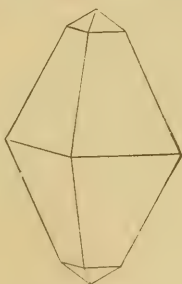


Fig. 129

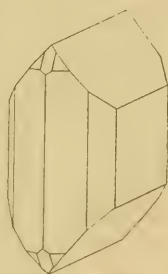


Fig. 130



Fig. 131

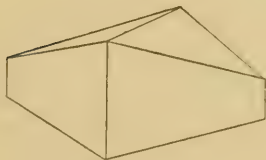


Fig. 132

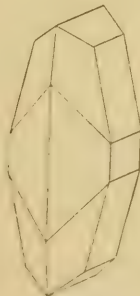


Fig. 133



Fig. 134

As in the case of the prisms there are macro and brachy pyramids bearing relations to the unit pyramid analo-

gous to those described under the prisms. Some combinations in this group, which includes many important species, are shown in fig. 128-34.

Hemimorphic group

The comparatively few species crystallizing in this group occur in forms which are symmetric to two planes of symmetry passing through the basal axes and intersecting in the vertical axis which is an axis of binary symmetry. The two extremities of the vertical axis are not modified in the same way, giving a different termination to the two extremities of the crystal. The crystal of calamin shown in fig. 135 gives a good example of this type.

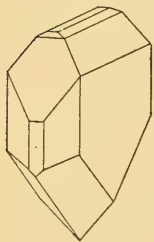


Fig. 135

Monoclinic system

Crystal forms in the monoclinic system are referred to three unequal uninterchangeable axes, two of which are inclined at an angle to each other, the third being perpendicular to the plane of the other two. The inclined axis which is placed vertical is designated by c , the other inclined axis by a and the normal or orthodiagonal axis by b .

A monoclinic crystal is represented conventionally with the orthoaxis (b) extending from right to left and the clinoaxis (a) dipping downward from back to front, the acute angle between the vertical and clino axes being designated by β (fig. 136). The statements regarding axial ratio under the discussion of the orthorhombic system apply in the case of monoclinic species with the additional note that the angle β varies for every species and constitutes one of the factors to be determined.

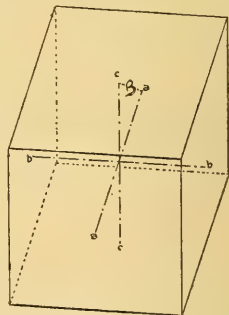


Fig. 136

Normal group

Forms of the normal group are symmetric to one plane of symmetry, which is the plane of the clino and vertical axes, and to one axis of binary symmetry, which is the orthoaxis (fig. 137).

Pinacoids. As in the normal group of the orthorhombic system, the monoclinic pinacoids are parallel to two axes and consist of pairs of parallel planes.

The basal pinacoid is parallel to both basal axes *a* and *b*.

The clinopinacoid is parallel to the clino and the vertical axis.

The orthopinacoid is parallel to the ortho and the vertical axis.

Fig. 136 shows the intersection of these three pinacoids.



Fig. 137

Prisms. The monoclinic or inclined rhombic prism cuts both horizontal axes and is parallel to the vertical axis. The clino and ortho prisms of this group are entirely analogous, in their relations to the unit prism, to the macro and brachy prisms of the preceding system. Fig. 138 shows an inclined rhombic prism terminated by a basal pinacoid.

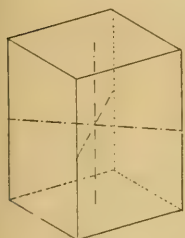


Fig. 138

Domes. The clinodome (fig. 139) consists of four faces parallel to the clinoaxis cutting the ortho and vertical axes; the faces are parallel in opposite pairs. The four faces which are parallel to the orthoaxis and intersect the other two, by reason of the lack of symmetry constitute two pairs of planes which

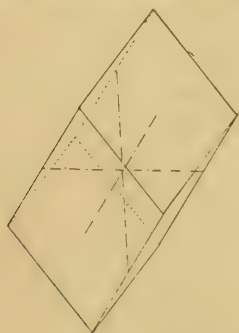


Fig. 139

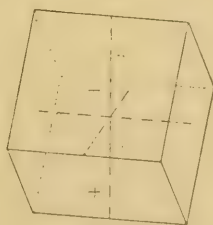


Fig. 140

are known as hemiorthodomes, the planes lying in the acute angle β being known as plus and those in the obtuse angle as minus. The plus and minus hemiorthodomes are shown in fig. 140.

Pyramids. For the same reason that the above mentioned faces are hemiorthodomes, the monoclinic forms which cut all three axes are hemipyramids. Faces in the acute angle β are plus hemipyramids and those in the obtuse angles are minus

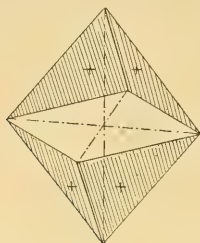


Fig. 141

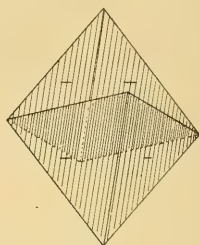


Fig. 142

hemipyramids (fig. 141, 142). As in the case of the prisms there are unit, ortho, and clino hemipyramids.

Some combinations in the group are given in fig. 143-148.

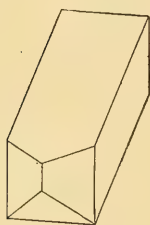


Fig. 143

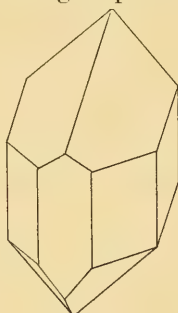


Fig. 144

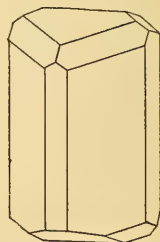


Fig. 145

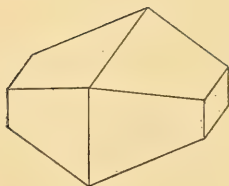


Fig. 146

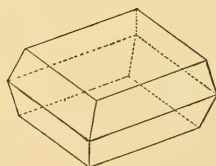


Fig. 147



Fig. 148

Triclinic system

The least symmetric of the six systems includes all forms which are referable to three unequal uninterchangeable axes

all of which are inclined to one another. The axes are designated as in the orthorhombic system. The angle between b and c is called α , that between a and c , β and that between a and b , γ . These angles are distinct for every triclinic species (fig. 149).

The similarity in molecular structure between minerals of the orthorhombic, monoclinic and triclinic systems indicated by their crystallization is further accentuated by their optical properties, crystals of all three systems being optically biaxial; that is, there are two directions in which polarized light is transmitted through them without double refraction. Lines bisecting the angle between these optic axes bear a close relation to the symmetry and outward form of the crystal.



Fig. 149

Normal group

Crystals occurring in this group are symmetric only to a center, which is the point of intersection of the crystallographic axes. This symmetry admits of forms occurring only in the pairs of faces;¹ thus all prismatic and dome forms which in the orthorhombic system are represented by four faces here occur as hemiprisms and hemidomes, two faces alone being required to satisfy the symmetry of the class. Similarly, pyramidal

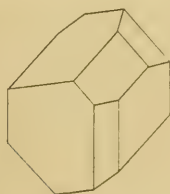


Fig. 150

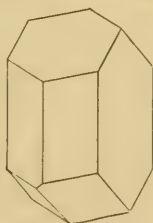


Fig. 151

forms which in the orthorhombic system consisted of eight faces are replaced by four complementary forms each consisting of two parallel planes. Compare model 11, which shows a triclinic or doubly inclined rhombic prism. With the above exceptions

¹ See p. 10, fig. 21.

the forms are identical in nomenclature with those of the orthorhombic system.

Two examples of triclinic crystals are shown in fig. 150 and 151 which represent respectively axinite and albite.

Variations in form

Reference has been made (p. 13) to the variations between the mathematical development of a crystal form or combination of forms and the actual mineral, crystallizing in those forms, as it is found in nature. This distortion is often misleading to a beginner, cubes and other forms of the isometric system being frequently elongated in the direction of one axis to such an extent as to resemble crystals of the tetragonal, the orthorhombic or even the hexagonal system. The reader is advised to observe carefully crystals of known minerals and to bear constantly in mind the symmetry of the group to which they belong.

Crystals of mineral species from the same locality show a predominance of one or two forms, which gives to such crystals a distinguishing character known as crystal habit. Minerals which occur widely distributed often show great variety in crystal habit, producing forms which are of great interest and beauty; quartz and calcite are notable examples.

Grouping of crystals

Though the crystals of many minerals occur isolated and developed alike on all sides, having somewhat the regularity of the ideal representations, it is far more common to find them grouped together in clusters, lining the interior of cavities, springing from the accompanying rock or lying embedded in the matrix. In some species the crystals show a tendency to arrange themselves in pairs, the faces of one individual being symmetrically disposed with respect to the other but in reverse position. This intergrowth of like crystals produces what is known as a twin crystal, the resulting solid being frequently of considerable complexity. A twin crystal may be recognized by reentrant angles which distinguish it from a simple crys-



1 Quartz, New Baltimore N. Y.



2 Calcite, Fontainebleau, France

tal, all the dihedral angles of which slope outward. A twinned octahedron is shown in fig. 152; the penetration twin cube, common in fluorite is shown in fig. 153 (compare also pl. 18₁); a scalenohedron of calcite twinned parallel to the basal plane is

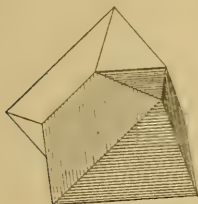


Fig. 152

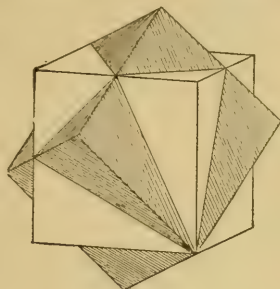


Fig. 153

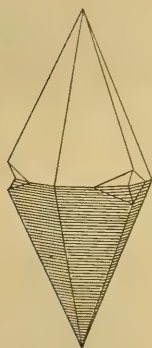


Fig. 154

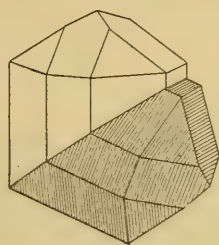


Fig. 155

shown in fig. 154, and a tetragonal twin of cassiterite in fig. 155. Aggregations of crystals frequently occur grouped in parallel position as shown in pl. 1₁.

Surface irregularities

Surface irregularities, occurring as they do on like faces of some crystals, often constitute a valuable means of determining the symmetry and consequently the group and system. Such markings on the faces of pyrite have been noticed in a former paragraph.¹ They are due in general to various causes which interrupt the perfect growth of the individual, producing low parallel furrows called striae or striations, angular depressions or prominences and dull faces. Curved faces are sometimes produced, as in the case of diamond.

¹ See p. 16.

Inclusions

Foreign bodies inclosed within a crystal are described under the general name of inclusions. They may be solid, liquid or gaseous in nature and organic or inorganic in origin. In general, inclusions result from rapid crystallization, as in the case of the calcite crystals shown in pl. 1₂; these show the typical rhombohedron of calcite, though containing a large percentage of the quartz sand carried by the solution from which they were crystallized.

Crystalline aggregates

Under this head are included the great majority of mineral specimens made up of aggregates of imperfect crystals. Many masses of material which appear to have no crystalline structure can be proved by optical and other physical tests to be composed of crystalline grains.

1 Columnar structure. Minerals possessing a columnar or fibrous structure present the appearance of bundles of slender columns.

parallel columnar, example beryl, pl. 2₁

bladed, example cyanite, pl. 2₂

fibrous, example serpentine (chrysotile) pl. 3₁

2 Lamellar structure. The mineral is composed of layers or leaves.

curved lamellar, example talc, pl. 3₂

foliated or micaceous, example muscovite, pl. 4₁

3 Granular structure. The crystalline particles consist of angular grains of about the same size.

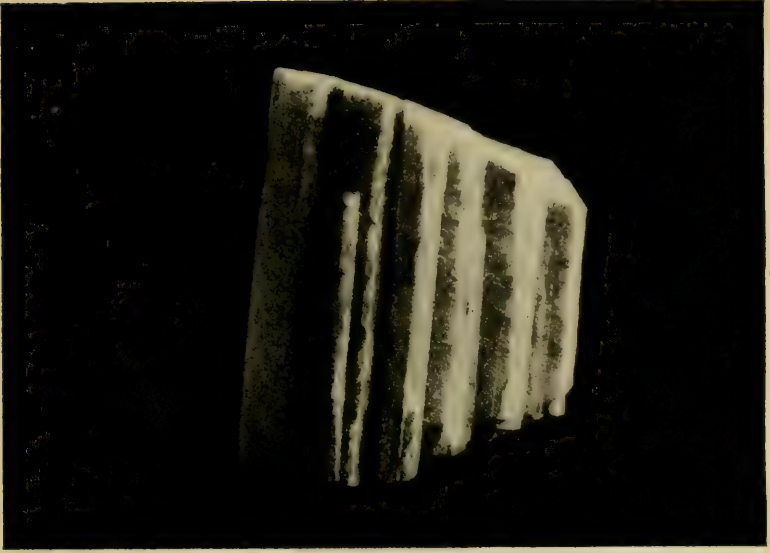
coarse granular, example magnetite, pl. 4₂

fine granular, example dolomite (marble), pl. 5₁

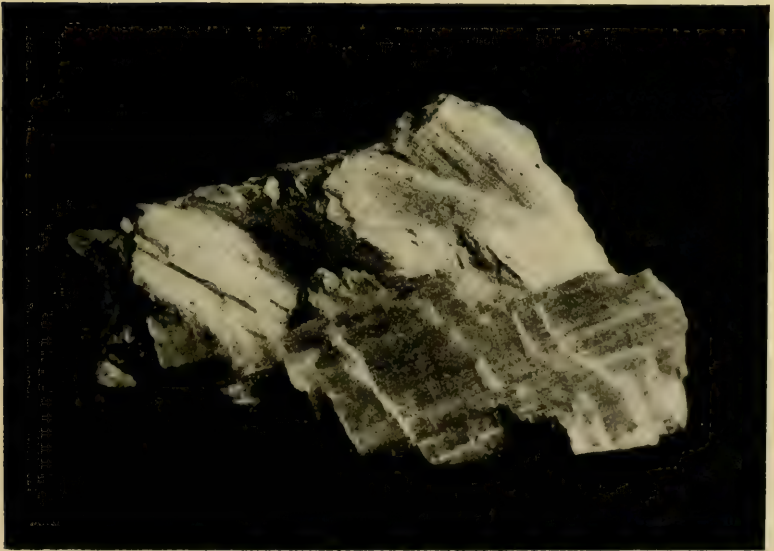
4 Imitative shapes. The arrangement of masses of imperfect crystals often give rise to forms which resemble those of animate nature. The most important terms used to describe such forms are:

reniform, kidney-shaped, example hematite, pl. 5₂

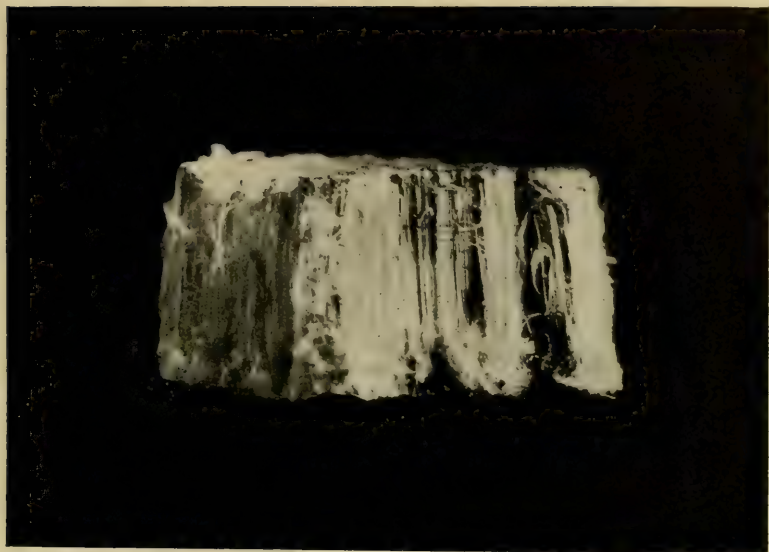
botryoidal, composed of globular individuals resembling a bunch of grapes, example quartz (chalcedony), pl. 6₁



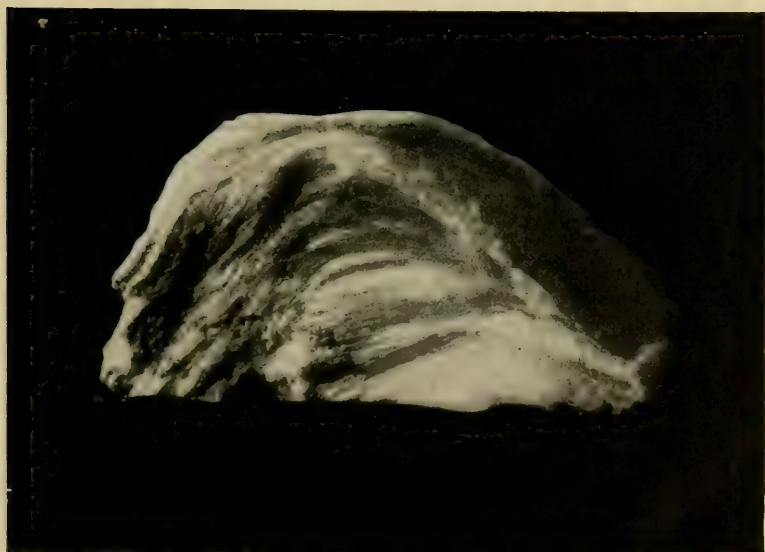
1 Beryl, Acworth N. H.



2 Cyanite, Litchfield Ct.



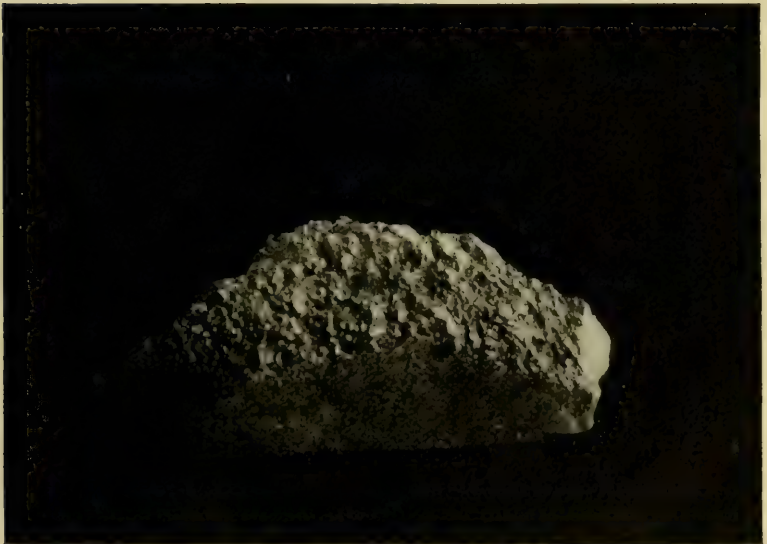
1 Serpentine (chrysotile), Danville, Quebec



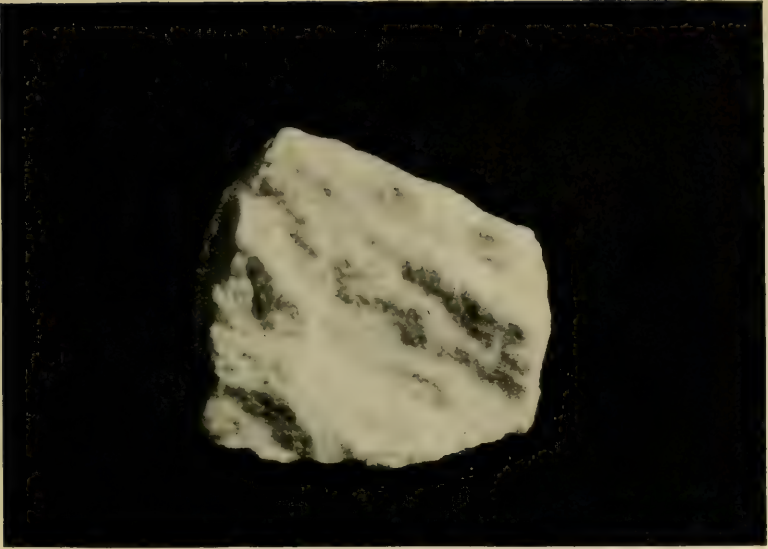
2 Talc, Smithfield R. I.



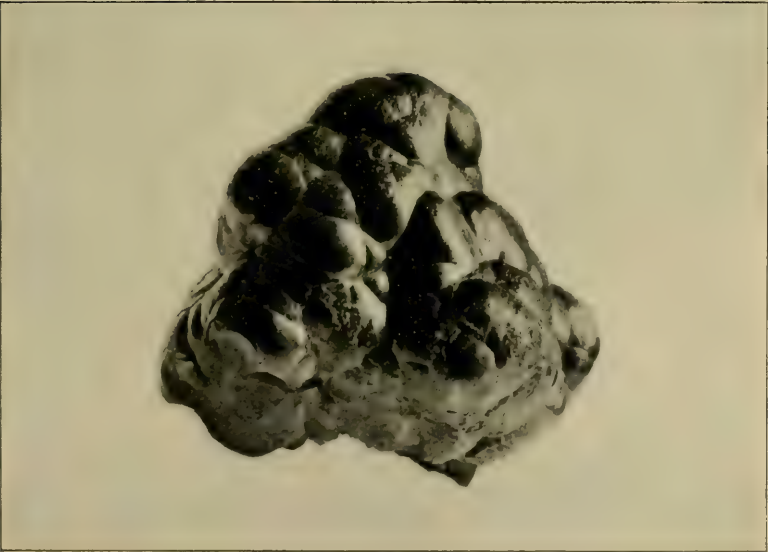
1 Muscovite, Stony Point N. C.



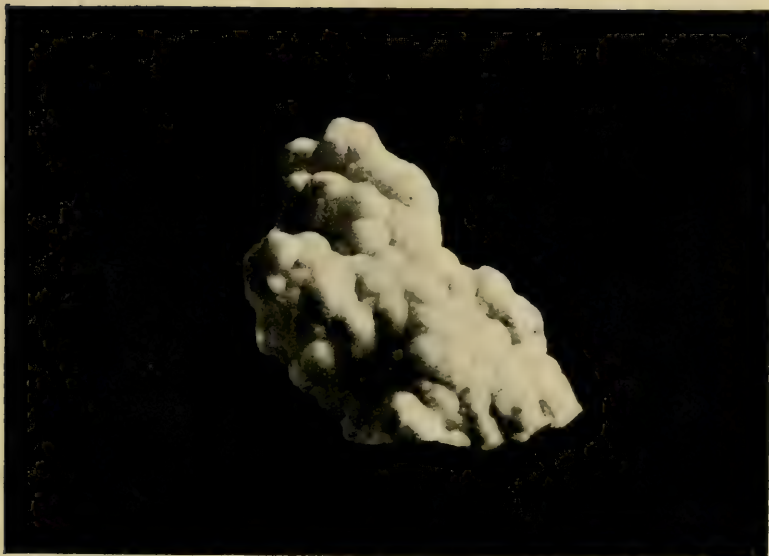
2 Magnetite, Mineville N. Y.



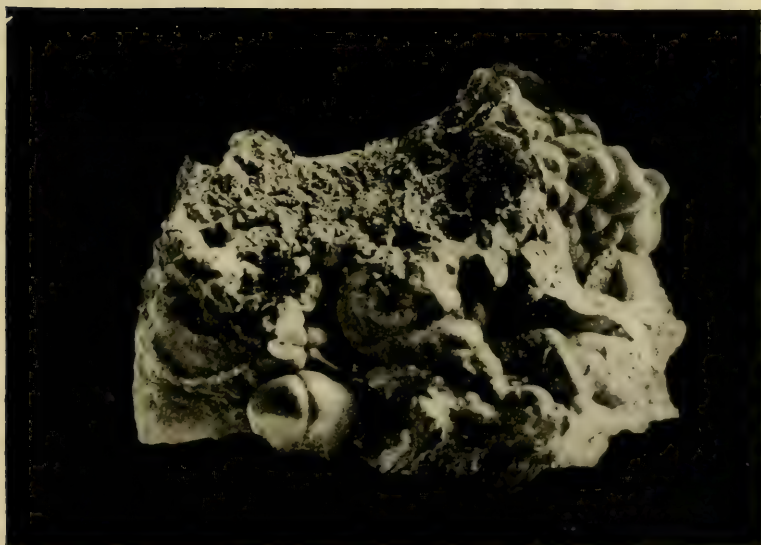
1 Dolomite, Dover, Dutchess co. N. Y.



2 Hematite, Cleator Moor, England



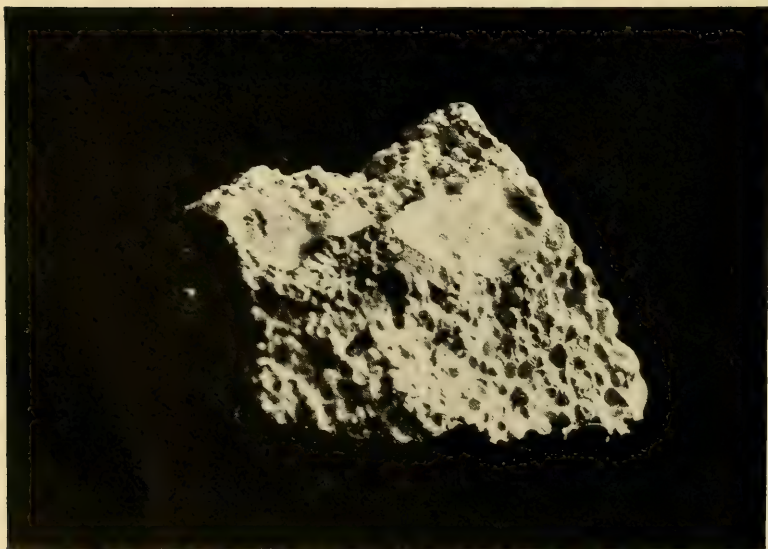
1 Quartz (chalcedony), Rocky mountains



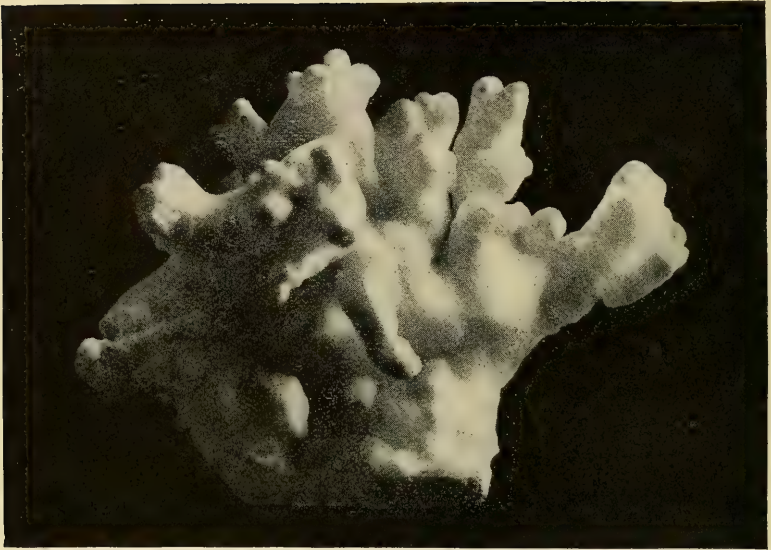
2 Malachite, Bisbee Ariz.



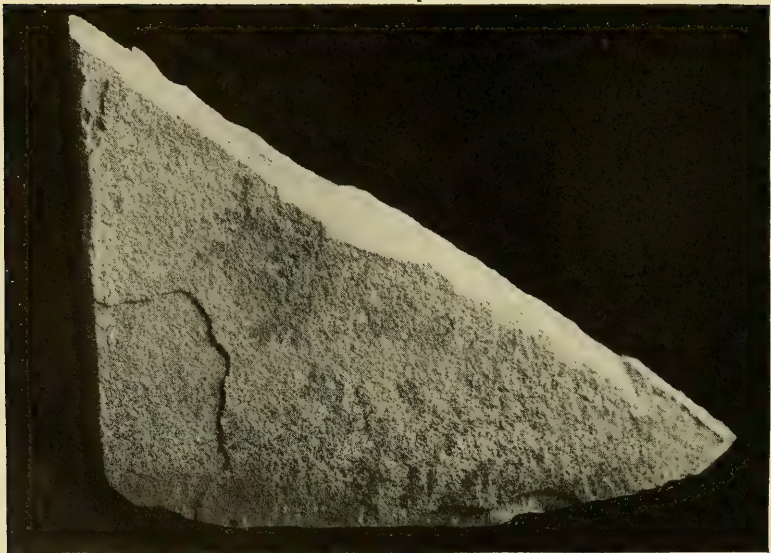
1 Pectolite, West Paterson N. J.



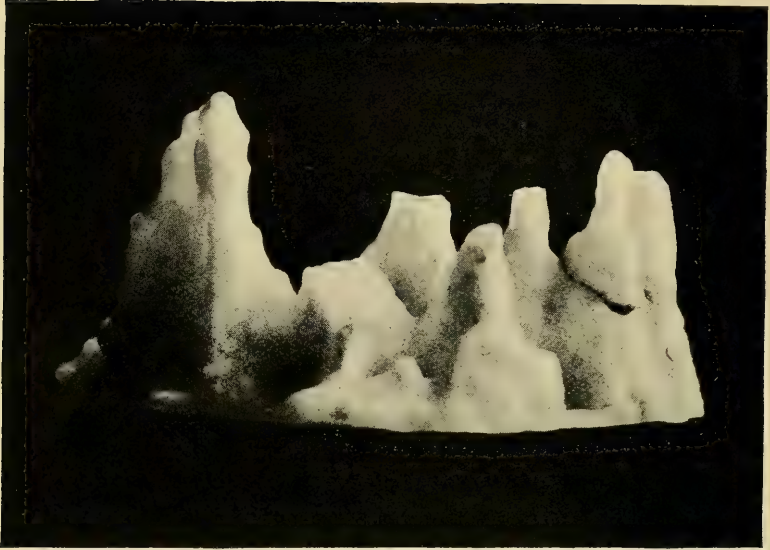
2 Calcite (pistolite), Karlsbad, Bohemia



1 Aragonite (flos ferri), Dubuque Ia.



2 Pyrolusite (dendrite) Middle Granville N. Y.



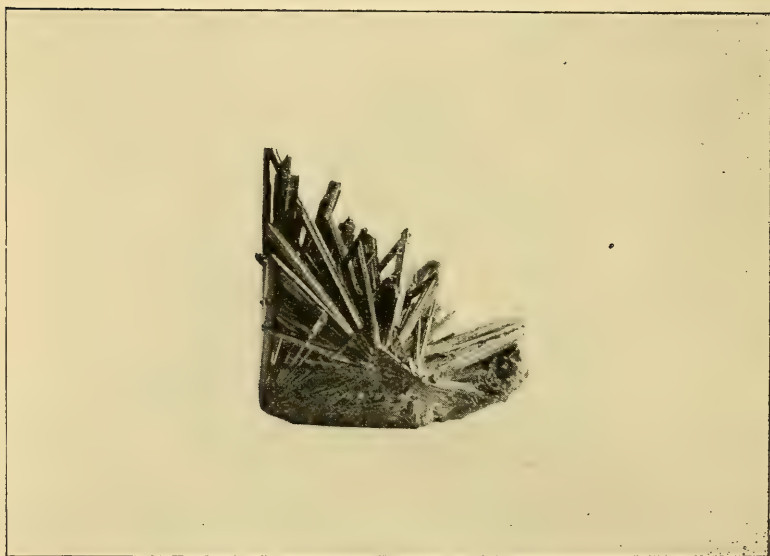
1 Calcite (stalagmite), Howes Cave N. Y.



2 Stibnite, Felsöbánya, Hungary



1 Millerite, Antwerp N. Y.



2 Stibnite, Kremnitz, Hungary

- mamillary, like the botryoidal but composed of larger and flatter protuberances, example malachite, pl. 6₂
- globular, imperfect spheres of radiating fibers, examples wavellite, pectolite, pl. 7₁
- oolitic, composed of small rounded grains, like the roe of fish, example calcite, pl. 7₂
- coralloidal, consisting of branching forms like coral, example aragonite, pl. 8₁
- dendritic, in branching treelike forms, example pyrolusite, pl. 8₂
- stalactitic, in pendant columns from the roofs of caves, formed by percolation of water carrying dissolved material, example calcite, limonite, pl. 9₁
- acicular, slender, needlelike forms, example stibnite, pl. 9₂
- capillary, hairlike, example millerite, pl. 10₁
- reticulated, interlaced fibers like a net, example stibnite, pl. 10₂.

Cleavage

Closely related to the crystalline structure of a mineral is the tendency, common in a varying degree to most mineral species, to break or split parallel to certain crystallographic planes. This tendency, which is called cleavage, takes place along the lines of minimum cohesion. Thus in a cube, the molecular arrangement of which is shown in fig. 2, it would be reasonable to expect cleavage to take place along planes parallel to the cube faces, that is, along the planes of molecular crowding. In fig. 156, assuming the dots to represent the position of molecules, the lines of least resistance to cohesion and consequently the lines of cleavage would be the vertical and horizontal rather than either of the inclined lines because the parallel lines of molecules on either side of the vertical and horizontal directions are further apart and consequently the attractive force between adjacent molecules would be least along these lines.

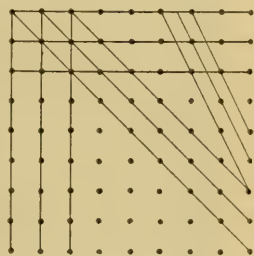


Fig. 156

In isometric minerals cleavage takes place parallel to the

faces of the cube, octahedron or dodecahedron. A good example of cubic cleavage is presented by the specimen of galena shown in pl. 11₁.

Tetragonal and hexagonal minerals show basal, prismatic or more rarely pyramidal cleavage. Rhombohedral cleavage is common among minerals crystallizing in the rhombohedral division of the hexagonal system. The rhombohedral cleavage of calcite is shown in pl. 11₂.

In the orthorhombic system cleavage parallel to one or more pinacoids is common, also prismatic cleavage. Clinodiagonal cleavage, parallel to the clinopinacoid, is found in many monoclinic species; also basal and prismatic cleavages and occasionally cleavage parallel to the hemipyramids as with gypsum.

In the triclinic system it is customary to select the axes so as to make the cleavage directions parallel to the pinacoids.

The parallel planes produced by cleavage may sometimes be advantageously observed by holding the specimen so as to reflect the light from a prominent face, and noting how the cleavage faces, previously hidden by the rough surface of the specimen, catch and reflect back the light. Cleavage is also evidenced by reflections from the interior of the crystal, incipient cracks and many other traces which appeal to the eye of a trained observer.

Fracture

The fracture of a mineral is observed on a broken surface other than a cleavage plane. It may be:

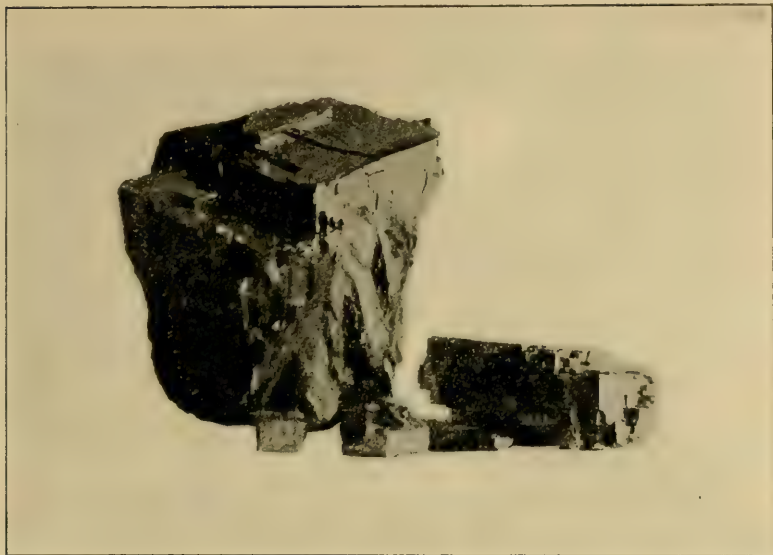
- 1 conchoidal, with a smooth, curved surface like broken glass or porcelain;
- 2 even, with more or less regular depressions and elevations;
- 3 uneven, with a rough, irregular surface;
- 4 hackly, with sharp, jagged elevations like broken iron.

Hardness

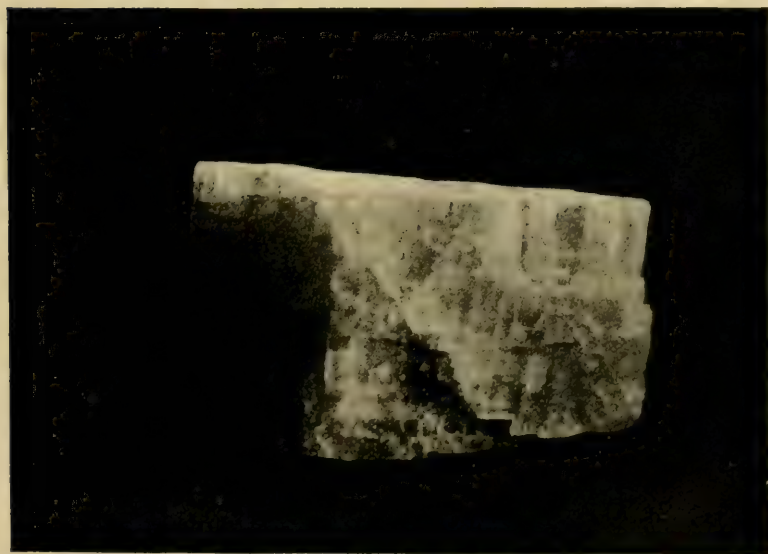
The degree of resistance offered by the smooth surface of a mineral to abrasion is known as hardness. A relative scale of hardness of 10 common minerals is arranged as follows:¹

1 talc	3 calcite (crystallized)
2 gypsum	4 fluorite

¹This scale of hardness was introduced by Mohs and is now generally accepted.



1 Galena, Rossie N. Y.



2 Calcite, Glenville, Schenectady co. N. Y.

5 apatite	8 topaz
6 orthoclase	9 corundum
7 quartz (rock crystal)	10 diamond

A sharp corner of the mineral to be tested for hardness is rubbed across the surface of each successive member of the scale, beginning with the high members, till one is found which is distinctly scratched; the hardness thus determined lies between that of the scale mineral scratched and the next higher member; thus, a mineral which scratches calcite but does not scratch fluorite has a hardness of 3-4. A good knife will scratch 6 with difficulty.

Tenacity

A mineral may be:

- 1 brittle, when it falls to powder before a knife or hammer and can not be shaved in thin slices;
- 2 sectile, when it can be shaved in thin slices but falls to powder under the hammer;
- 3 ductile, when slices shaved from it may be flattened under the hammer;
- 4 flexible, when it will bend without breaking.

Characters depending on light

Luster

Differences in the luster of minerals are due to the light which is reflected from the surface; luster is independent of the color of the mineral. The luster of a mineral may be:

- 1 metallic, the luster exhibited by opaque metals, example pyrite;
- 2 adamantine, the oily luster of the uncut diamond, example cerussite;
- 3 vitreous, the luster of glass, example quartz;
- 4 resinous, the luster of yellow resin, example sphalerite;
- 5 greasy, the luster of oiled glass, example elaeolite;
- 6 pearly, the luster of the mother of pearl, example brucite;
- 7 silky, the luster of silk produced by a fibrous structure, example satin spar;
- 8 dull, void of luster, example kaolin.

Color

The color of a mineral is a matter of considerable variation, different specimens of the same species frequently differing through quite a wide range. This is notably so of the minerals of nonmetallic luster, as in the case of fluorite, which is found in white, yellow, green, rose-red, violet, blue, brown, wine color and greenish blue varieties. Metallic minerals are far more constant in color, a fresh fracture ordinarily giving the characteristic color of the species.

The color of the fine powder of a mineral is known as its streak and often differs from the color of the hand specimen. With soft minerals it may be readily obtained by rubbing the specimen on a piece of unglazed porcelain.

General principles of chemical classification

A substance which can not be decomposed or separated into simpler constituents is known as an element. About 70 such elements are recognized at present, less than half of which are of common occurrence. It is estimated¹ that 99% of the solid crust of the earth for a depth of 10 miles is composed of eight elements as follows:

oxygen	47.3%	calcium	3.8%
silicon	27.2	magnesium	2.7
aluminium	7.8	sodium	2.4
iron	5.4	potassium	2.4

For convenience elements are represented in chemical formulas by symbols which consist of the initial letter of the name of the element or an abbreviation composed of two letters, thus:

P=phosphorus	Na=sodium (natrium)
S=sulfur	Ca=calcium
O=oxygen	Pb=lead (plumbum) etc.

In the appendix will be found a table giving the names of the elements, their symbols and their relative atomic weight. Some elements occur native or alone in nature, such as gold, silver, copper, carbon, sulfur, etc. but the great majority of

¹Clarke, F. W. Relative abundance of the chemical elements. Phil. soc. of Washington. Bul. 9. 1889. p. 138.

mineral species are compounds of two or more elements united according to the laws of chemical combination.

A few predominant chemical compounds make up the greater part of the earth's crust. Of these, silica (SiO_2), a combination of silicon and oxygen, is the most important. This forms quartz and its numerous varieties, amethyst, agate, flint, etc.; and, combined with other elements, often with an extremely complicated chemical composition, silica makes the great group of silicates, which includes the larger number of the common rock forming minerals. Oxygen combined singly with an element forms another great group, the oxids to which many ores, such as those of iron, belong. Combined with aluminium oxygen forms alumina (Al_2O_3), a common mineral; and this combined with silica is the base of our clays and an important rock constituent. Oxygen with carbon and some other elements forms the carbonates to which limestone belongs; with sulfur and some other elements it forms the sulfates (gypsum, etc.); and with phosphorus and another element the phosphates. Sulfur, without oxygen, combined with an element forms a sulfid, fluorin a fluorid, chlorin a chlorid, etc.¹

The most satisfactory classification of mineral species is that based on chemical composition. Under sections having a similar chemical composition, species are divided into groups which usually embrace minerals closely allied crystallographically. Throughout the succeeding section the chemical composition of each species is given in words and symbols, which, while appealing specially to the chemist, can be readily understood by those who bear in mind that in each mineral those elements are found whose abbreviations appear in the symbol. Numbers below the sign indicate the relative number of atoms of each element. Example, realgar is a sulfid of arsenic, and the signs of sulfur (S) and arsenic (As) appear in its symbol (AsS); or, there is one atom of sulfur and one of arsenic united, but arsenic is relatively heavier than sulfur (see table of elements in appendix) therefore the composition by weight is in percentages: sulfur, 29.9; arsenic, 70.1; 100.

Isomorphism, dimorphism, etc.

It has been found in a number of cases that mineral species so related by chemical composition as to form part of one of the

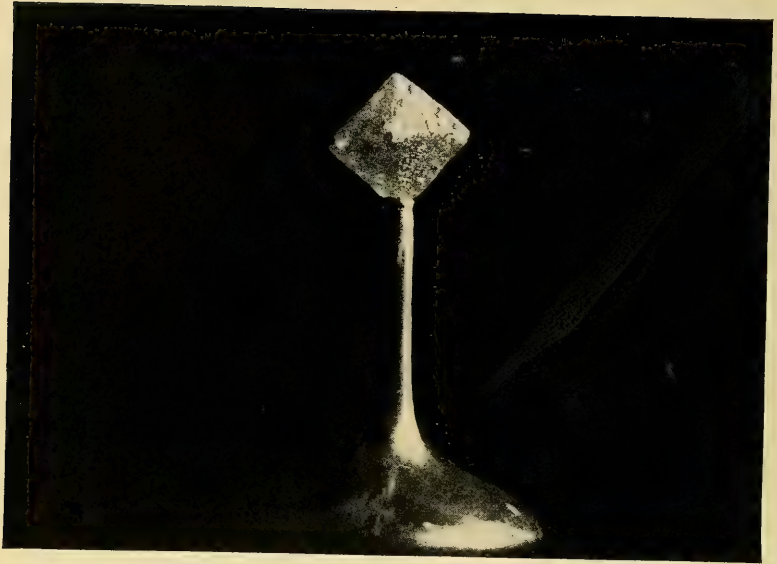
¹Tarr, Ralph S. Economic geology of the U. S. 1894.

mineralogic divisions, such as carbonates, oxids, silicates, etc. also present a strikingly close similarity in the arrangement of their molecules as shown by their crystallization, cleavage and optical properties; minerals so related are said to form an isomorphous group.

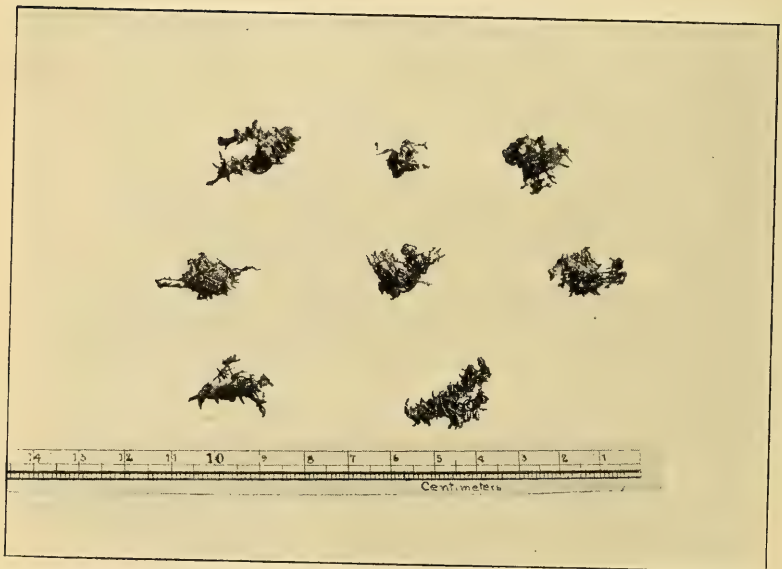
In some instances a combination of elements occurs crystallized in two or more series of crystal forms which are notably separate and distinct and frequently present the symmetry of different systems; this gives rise to two (sometimes three) species of identical chemical composition and is known as dimorphism (or trimorphism where three species are concerned). A very good example of dimorphism is presented by the carbonate of calcium, which crystallizes in the rhombohedral group of the hexagonal system as the mineral calcite and in orthorhombic forms as the mineral aragonite. Calcite stands at the head of an isomorphous group of carbonates which all crystallize in very closely related rhombohedral forms. Similarly aragonite represents an isomorphous group of orthorhombic carbonates which agree very closely in axial ratios and crystal habit.

Pseudomorphs

Not uncommonly the composition of a crystallized mineral will undergo some change by reason of the addition, loss or replacement of one or more elements. Thus pyrite, which is a sulfid of iron, may, under certain conditions, undergo a change of composition, the sulfur being replaced by oxygen and some water and the resulting mineral will have the composition of limonite. This change is *not* accompanied by a corresponding change in external form, therefore the altered substance will present the crystallization and structure of the original mineral but the composition, color, luster and hardness of the mineral to which it has altered. Such a product of alteration is called a pseudomorph. In the above instance limonite is said to form a pseudomorph after pyrite.



1 Diamond, Kimberley, South Africa



2 Silver, Freiberg, Saxony

PART 2

DESCRIPTION OF MINERAL SPECIES

NATIVE ELEMENTS

Native elements are divided into two groups, metals and non-metals; between these two is inserted a series of semimetals which partake, sometimes of the nature of the metals and sometimes of the nature of the nonmetals.

NONMETALS

Diamond, carbon C

Diamonds are usually found in isolated, rounded, isometric crystals, octahedrons or modified octahedrons (pl. 12₁). They are transparent, with an adamantine luster, like oiled glass, and are commonly colorless or faintly tinted.

The diamond is the hardest substance known; this, together with its high refractive power and easy octahedral cleavage, renders it particularly suited for a gem stone, while the comparative rarity of unflawed crystals and the difficulty experienced in cutting them owing to their extreme hardness, combine to make diamonds objects of considerable value. Massive and impure varieties are used for abrasive materials and in such cutting machinery and tools as require very hard edges. These massive varieties are known as bort and carbonado. Bort consists of rounded forms of confused crystalline structure. Carbonado is a black, massive form without cleavage.

Diamonds occur chiefly in alluvial deposits of gravel, sand or clay, the associated minerals being those common to granitic rocks. Diamonds were formerly extensively obtained from India, which has produced many remarkable gems; later they were discovered in Brazil, but the present great diamond producing region is South Africa.

Graphite, carbon C

Like the diamond, graphite is composed of carbon sometimes containing iron, clay, sand or other impurities. It occurs in soft black flakes or scales which are rarely hexagonal in shape.

Graphite has a basal cleavage, splitting into plates which are flexible and slightly sectile, its luster is metallic and its color black to gray.

Graphite occurs in beds and as embedded grains in granite, gneiss, mica schist and crystalline limestone. It is quite widely distributed throughout New York, appearing notably at Hague from which locality a large proportion of the American output is obtained.

Graphite is used largely in the manufacture of crucibles and other refractory vessels, in the so called "lead" pencils and for many other purposes.

Sulfur S

Sulfur is found in orthorhombic pyramids as in fig. 157, or modifications of the same, fig. 158, the crystals are often transparent and in the Sicilian variety extremely beautiful. Sulfur is also found massive, reniform, stalactitic, incrusting other

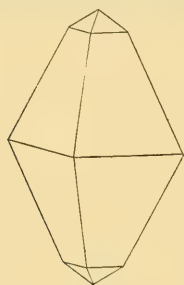


Fig. 157

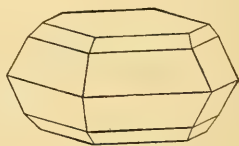


Fig. 158

Sulfur

minerals, as in the varieties found near hot springs and in the form of a powder. The color is commonly a lemon-yellow but not infrequently shades into yellow orange, brown or gray. The luster is resinous and the streak white. Sulfur is found notably in the regions of active or extinct volcanic action, as a deposit from hot springs and as a product of the decomposition of sulfids and sulfates. It occurs in large deposits in the island of Sicily; it is also distributed to some extent throughout the western part of the United States and has been known to occur sparingly near the sulfur springs of New York.

Sulfur is used in large quantities in the manufacture of sulfuric acid, gunpowder, matches etc.

SEMIMETALS

Arsenic. Arsenic is usually found in massive forms, the structure being reniform, and is composed of concentric layers which can frequently be separated with ease. Crystals are quite rare. The color is tin-white, tarnishing to black, and the luster is nearly metallic. It occurs in veins in crystalline rocks and in the older schists.

Antimony. Usually found in massive forms, lamellar or radiated, of a tin-white color and metallic luster. Rhombohedral crystals are of rare occurrence.

Bismuth. Bismuth is found in brittle, silver-white, arborescent forms which, on a fracture of the ground mass, resemble Hebrew characters; also foliated and granular. The luster is highly metallic and the color white, sometimes taking a reddish tinge. It is rarely found in distinct hexagonal crystals.

METALS

Gold Au

Gold is usually found alloyed with small amounts of silver and sometimes copper and rare metals. Distinct isometric crystals are rare though skeleton crystals and distorted octahedrons in wirelike, arborescent and reticulated shapes are quite common. Nuggets, grains and scales are also characteristic, usually disseminated through the gold-bearing rock in such small quantities as to be perceptible only by assay methods. It is of a fine yellow color, has a metallic luster and is extremely malleable and ductile.

Gold occurs in veins, usually in quartz rock, where it is associated with sulfids, specially pyrite. It is largely mined from superficial deposits of sand, gravel and boulders formed in the valleys and river bottoms from the erosion of higher rocks containing gold veins. These beds of gold-bearing material are called placers.

Gold is used chiefly for coinage, jewelry and gilding.

Silver Ag

Silver is found in nature quite pure though sometimes alloyed with gold, copper and other metals. Isometric crystals are of rather more frequent occurrence than in the case of gold; parallel groupings of cubes are quite common; these pass into distorted fernlike and wirelike forms similar to those shown in pl. 12₂. Silver is a soft, malleable metal, silver-white on the fresh fracture but tarnishing to dark gray or black.

Silver occurs in veins traversing gneiss, schist, porphyry and other rocks and is also associated with copper in calcite. It is commonly carried in small amounts by galena. Some of the more important localities where it is found are Kongsberg, Norway; Saxony; Peru; northern Mexico; also Michigan, Colorado, Idaho, Montana and Arizona. An unsuccessful attempt to mine silver in the vicinity of Ossining was made early in the last century.

Silver is used for much the same purposes as gold.

Copper Cu

Copper occurs in soft, red, malleable crystals of the isometric system, disseminated masses and sheets. The common crystal forms are the cube and tetrahexahedron alone or in combination as shown in fig. 159; distorted and twisted crystals pass from parallel groups to branching arborescent forms (pl. 13₂). Twins are quite common but are, however, almost invariably distorted. The luster is metallic and the color and streak red, the former often tarnished nearly black.

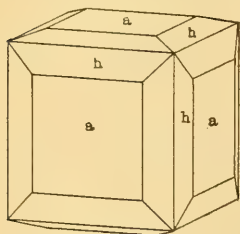
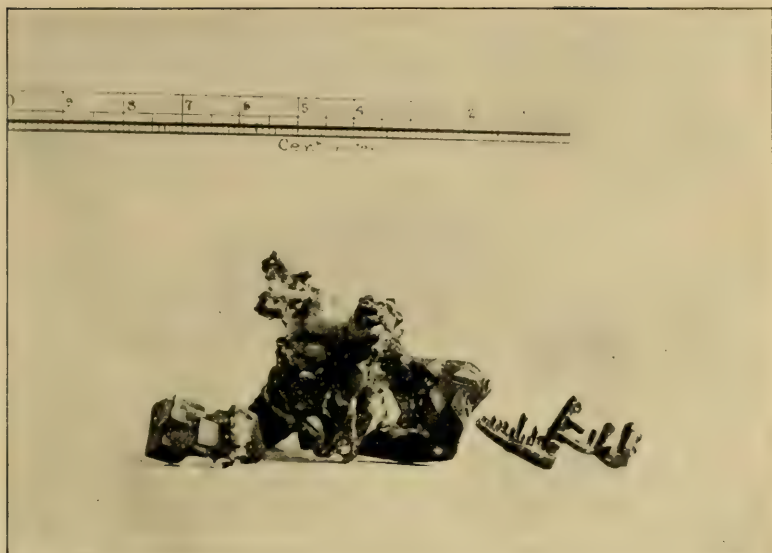


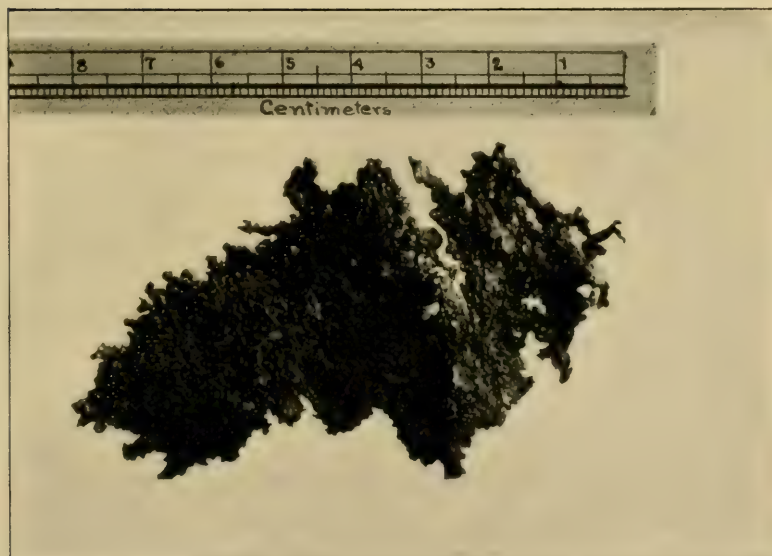
Fig. 159
Copper

Copper occurs in beds and veins with native silver and the various copper ores and is frequently found near dykes of igneous rock. In the Lake Superior region in northern Michigan it occurs in dolerite and sandstone associated with calcite, datolite, analcite, etc.

Copper is largely used in electric work and in alloys such as brass, bronze, bell metal, German silver, etc.



1 Copper, Lake Superior, Mich.



2 Copper, Yadkin gold mine, N. C.

Mercury Hg

Mercury is remarkable as being almost the only mineral occurring in the liquid state. It is found in small white metallic globules scattered through its gangue, which is usually its own sulfid, cinnabar.

It occurs chiefly in clay shales and schists.

Platinum Pt(Fe)

Platinum as it occurs in nature is almost invariably alloyed with iron and usually with small quantities of the rarer metals. It is found in small malleable grains or nuggets of a steel-gray to white color scattered through alluvial sand and associated with gold. It is often mined with the gold from these placer deposits.

A large proportion of the production of platinum is taken from the placer deposits of the Ural mountains. It is also known to occur in Borneo, Brazil and the United States of Colombia.

Platinum is practically infusible and is consequently used to a large extent for chemical apparatus which is required to resist a high degree of heat.

Iron

See under meteorites.

SULFIDS, SELENIDS, TELLURIDS, ARSENIDS, ANTIMONIDS

SULFIDS, ETC. OF THE SEMIMETALS

Realgar AsS

Realgar is a monosulfid of arsenic. It occurs in translucent, orange-red granular masses with a resinous luster, also in transparent monoclinic crystals, which are short prismatic in habit and are striated vertically.

Realgar is found in Hungary and in the island of Borneo; it also occurs in Utah, California and Wyoming. It is used as a pigment.

Orpiment As₂S₃

Orpiment is the trisulfid of arsenic. It sometimes occurs in imperfect orthorhombic crystals but more generally in foliated or columnar masses of a brilliant lemon-yellow. When foliated

it can be readily separated into thin, flexible, nonelastic scales. Orpiment is soft (H-1.5-2), slightly sectile and has a resinous or pearly luster.

It is often found associated with realgar. The principal localities are Hungary, Borneo, Turkey; also Wyoming, Utah and Nevada. It is found in the form of powder at Edenville N. Y.

Stibnite (antimony glance) Sb_2S_3

Stibnite is the trisulfid of antimony containing sulfur 28.6%, antimony 71.4%.

It is found in orthorhombic crystals of prismatic habit; a typical termination is shown in fig. 160. The crystals, which are frequently acicular, show a tendency to arrange themselves in radiating and reticulated groups (pl. 9₂, 10₂). They are grooved and striated vertically and are sometimes bent and twisted. The color and streak are lead-gray and the luster metallic with brilliant reflecting surfaces. Stibnite is quite soft, the hardness being about 2, and has an easy cleavage parallel to the vertical axis. It often occurs in massive forms coarse or fine columnar and sometimes granular.

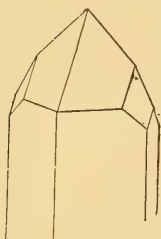


Fig. 160
Stibnite

Stibnite occurs in Hungary, Japan and New South Wales; also in Nevada, Idaho, Utah, California, Arkansas and Nova Scotia.

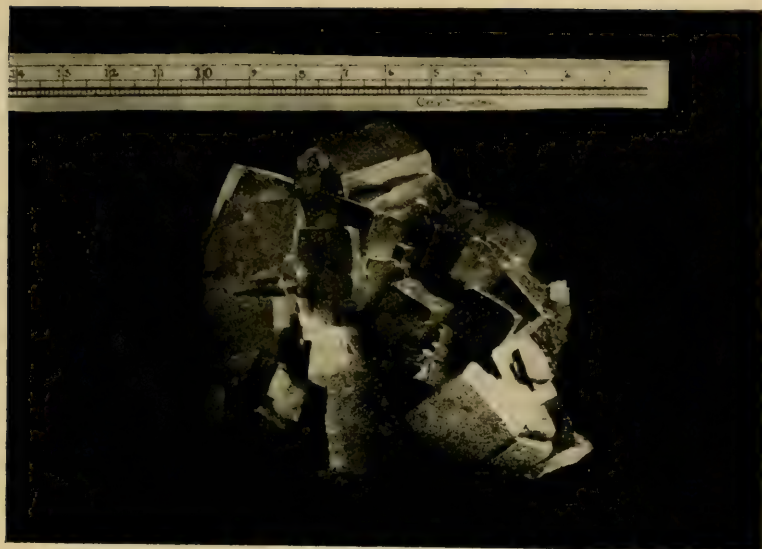
Stibnite is the chief source of antimony and is also used quite extensively in the production of safety matches, percussion caps, fireworks and rubber goods, and in the refining of gold.

SULFIDS, ETC. OF THE METALS

Galena (galenite, lead glance) PbS

This important mineral is the sulfid of lead, containing sulfur 13.4% and lead 86.6%.

It is found crystallized and massive and is characterized by a very marked cubic cleavage (pl. 11₁). The crystals, some of which are shown in fig. 161-63 are isometric, the cube and octahedron being the prevailing forms. The crystal group shown in pl. 14₁, gives some idea of the crystal habit and irreg-



1 Galena, Galena Ill.



2 Chalcocite, Bristol Ct.

ular grouping. Distorted crystals are frequent, as in the specimens from Gonderbach, Nassau (N. Y. state museum collection). Twin crystals are also common. Galena is lead-gray in color and streak; it is soft (H-2.5) and very heavy. The luster is

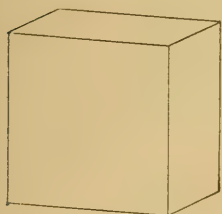


Fig. 161

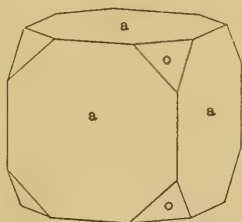
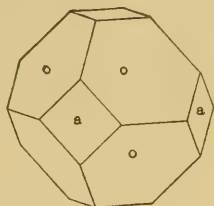
Fig. 162
Galena

Fig. 163

metallic and bright on a fresh fracture but apt to become dulled and oxidized on crystal faces which have been long exposed.

Galena is very widely distributed. It occurs in veins in crystalline and noncrystalline rocks and is commonly associated with other sulfids and other salts of lead, which latter are frequently the result of its alteration. In addition to numerous and important foreign localities it occurs in the United States in extensive deposits in Missouri; also in Illinois, Iowa, Wisconsin, and in New York at Rossie, St Lawrence co., Ellen-ville, Ulster co. and Wurtzboro, Sullivan co.

Galena is the principal ore of lead and is extensively worked in Colorado, Idaho, Montana and other western states for the silver it usually contains.

Argentite (silver glance) AgS

The sulfid of silver contains 12.9% sulfur and 87.1% silver.

The crystals are isometric, of an octahedral habit, and are often modified by the cube; distorted forms are quite common as are parallel groupings which produce arborescent forms. It also occurs massive. Argentite is soft and sectile; it has a lead-gray color and metallic luster.

It occurs at Freiberg, Germany; in Hungary, Norway, Cornwall, Peru, Chile and Mexico. In the United States it is found in Nevada and Arizona and in the Lake Superior region of Michigan. It is mined for silver.

Chalcocite (copper glance) Cu_2S

Chalcocite is a copper sulfid containing 20.2% sulfur and 79.8% copper.

Though often occurring in orthorhombic crystals (pl. 14₂) chalcocite is more frequently met with in masses which somewhat resemble argentite but are much more brittle; it may be distinguished from bornite by the absence of the characteristic red-brown color peculiar to bornite. The luster is metallic and the streak and color lead-gray, the latter taking a dull black tarnish on exposure.

Chalcocite occurs commonly associated with other copper minerals. Beautiful specimens of this mineral are found in the Cornwall mines. It occurs also in Bohemia, Saxony, Mexico and South America. Interesting crystals are found at Bristol Ct., and massive varieties to considerable extent at Butte Mont.

Chalcocite is an ore of copper.

Sphalerite (zinc blende or blende) ZnS

The zinc sulfid known as sphalerite or blende contains 33% sulfur and 67% zinc.

Sphalerite often contains cadmium manganese and iron in small quantities. It crystallizes in the tetrahedral group of the

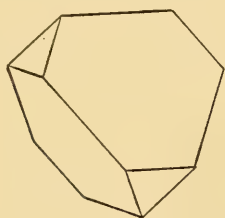


Fig. 164

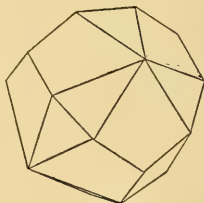


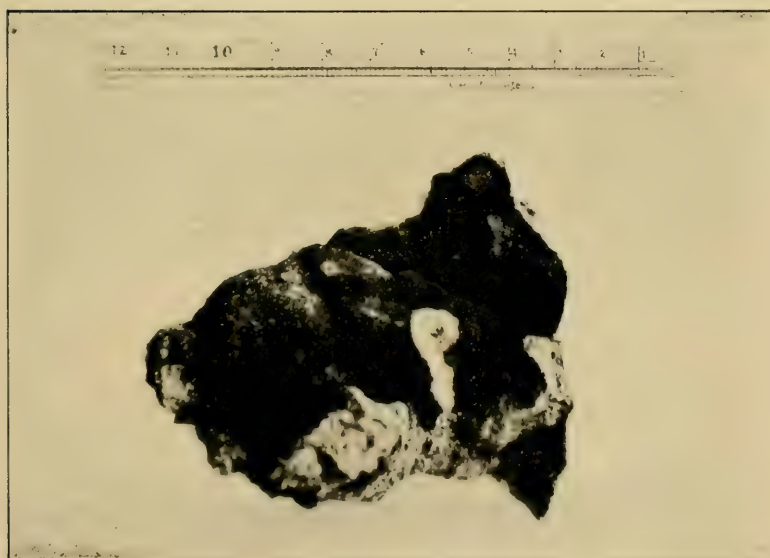
Fig. 165

Sphalerite

isometric system (fig. 164, 165). In specimens from some localities the modification of the dodecahedron shown in fig. 165 has a tendency by reason of repeated twinning to form a somewhat curved face as in the specimen shown in pl. 15₁. Massive varieties are very common and show a perfect dodecahedral cleavage. Compact masses of alternating layers of sphalerite and galena also occur. The color ranges from black through red, brown, yellow, green, to white, the more frequent shades being



1 Sphalerite, Joplin Mo.



2 Millerite, Gap mine, Lancaster co. Pa.

black, brown and yellow. The streak is yellowish brown to white and the luster resinous.

Sphalerite occurs in both crystalline and sedimentary rocks and is frequently associated with galena. Such an association is found in the extensive deposits of Missouri, Wisconsin, Iowa and Illinois. Sphalerite is found in several localities in England and Germany, also in Hungary, Sweden, Spain, etc. In New York it is found in small quantities in a number of places, notably at Wurtzboro, Sullivan co., Ellenville, Ulster co., at the Ancram lead mine in Columbia county, in the limestone of Lockport, Niagara co., and with calamin at Bethlehem Pa.

Besides being an important ore of zinc, sphalerite yields considerable cadmium.

Cinnabar HgS

The sulfid of mercury, cinnabar, contains 13.8% sulfur and 86.2% mercury.

The mineral is rarely found in hexagonal crystals of the rhombohedral-trapezohedral group; it is commonly met with in granular or earthy masses sometimes incrusting or as an earthy coating. Cinnabar is very heavy ($G=8.2$); this and its brilliant red streak usually serve to identify it. The color is cochineal-red to reddish brown and sometimes even inclining to black; the luster is adamantine to dull.

Cinnabar occurs in a variety of rock formations, being found in slate, shale, granite and porphyry, where it is associated with other sulfids. The principal localities are Almaden, Spain, southern Russia, southern Austria, China, Peru, and Mexico. California furnishes most of the American output.

Cinnabar is a valuable ore of mercury and was formerly ground for a pigment called vermilion. The pigment is now produced artificially.

Greenockite CdS

Greenockite, the sulfid of cadmium, contains 22.3% sulfur and 77.7% cadmium.

It usually occurs as a bright yellow powder coating sphalerite and rarely in dull yellow hexagonal crystals of the hemimorphic group. The crystals are nearly transparent and of a resinous luster.

Greenockite is found crystallized in Renfrewshire, Scotland, and, associated with sphalerite, at the Bohemian locality and in Pennsylvania and Missouri.

It is mined for cadmium with the sphalerite.

Millerite (capillary pyrites) NiS

Millerite, the sulfid of nickel, contains 35.3% sulfur and 64.7% nickel.

It crystallizes in the hexagonal system but the crystals are rarely of sufficient size to make this apparent, the lengthening of the crystals producing hairlike forms which often radiate from a center or form a mat or wad of interwoven individuals. The capillary crystals are sometimes grouped in crusts of columnar or radiated aggregates as in the specimen shown in pl. 15₂. The luster is metallic, the color a brass-yellow to bronze-yellow and the streak greenish black.

Millerite occurs in cavities as at the Antwerp locality, where it is found in hematite, or incrusting as at the Pennsylvania deposit where it overlies pyrrhotite. It is found in Bohemia, Saxony and Cornwall and in the United States in Lancaster county, Pa. and at Antwerp, Jefferson co. N. Y.

It is a source of nickel.

Niccolite (copper nickel) NiAs

Niccolite is the arsenid of nickel and contains 56.1% arsenic and 43.9% nickel; of which the arsenic is sometimes replaced in part by antimony or sulfur, and the nickel by a little iron or cobalt.

Hexagonal crystals of niccolite are rare, the mineral usually occurring in pale copper-red metallic masses of smooth, impalpable structure, with an uneven fracture.

In addition to the European and South American localities, niccolite occurs in the United States at Lovelock Nev., Till Cove, Newfoundland, Silver Cliff Col., Chatham Ct. and to a very limited extent at Franklin N. J.

It is mined for nickel.

Pyrrhotite (magnetic pyrites)

Pyrrhotite is a sulfid of iron of varying percentages of sulfur and iron and often containing nickel.

It is rarely found in distinct hexagonal crystals of tabular habit, the most common form of occurrence being as a massive metallic mineral of a bronze color possessing to a varying degree the property of attracting the magnet. It differs from pyrite, bornite and niccolite in color and in the magnetic property mentioned above.

Pyrrhotite occurs in gabbro and other igneous rocks and in schists; it is also found in meteorites. It is very widely distributed. The principal American localities are Sudbury Can. and Lancaster Gap Pa. at both of which places it is mined for the nickel it contains. A deposit of pyrrhotite was formerly worked at Anthony's Nose, Westchester co. N. Y.

Bornite (purple copper ore)

Bornite is a sulfid of copper and iron of variable proportions, the massive variety being probably a mechanical mixture with chalcocite. The crystallized mineral seems to conform quite closely to the formula which gives 28.1% sulfur, 55.5% copper and 16.4% iron.

The crystallized specimens show isometric forms with a cubic habit. The massive varieties have a granular to compact structure. The mineral is characterized by a metallic luster and a dark copper-red, pinchbeck-brown or purple color which tarnishes rapidly to iridescence.

Bornite occurs associated with the other copper minerals in Cornwall (crystalline), Chile, Peru, Bolivia, Mexico and Canada and in the United States at Bristol Ct. and near Wilkesbarre Pa.

It is mined for copper.

Chalcopyrite (copper pyrites) CuFeS_2

Chalcopyrite is a sulfid of iron and copper in the proportions, 35% sulfur, 34.5% copper and 30.5% iron. Variations from these proportions are often due to pyrite mechanically intermixed in the massive varieties.

The tetragonal crystals of chalcopyrite belong to the sphenoidal group and when in simple, unmodified forms resemble isometric tetrahedral types. Modified crystals such as those given in fig. 166, 167, however, clearly show the true symmetry

of the forms. Massive occurrences are common. Chalcopyrite has a bright metallic luster; the color is a brass-yellow, often tarnishing to colors resembling bornite.

It is widely distributed in veins and vugs in gneiss, crystalline schists and other metamorphic rocks and was probably formed

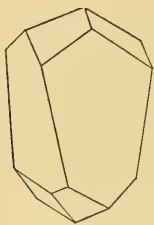


Fig. 166

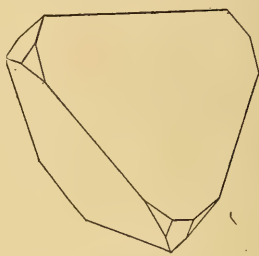


Fig. 167

Chalcopyrite

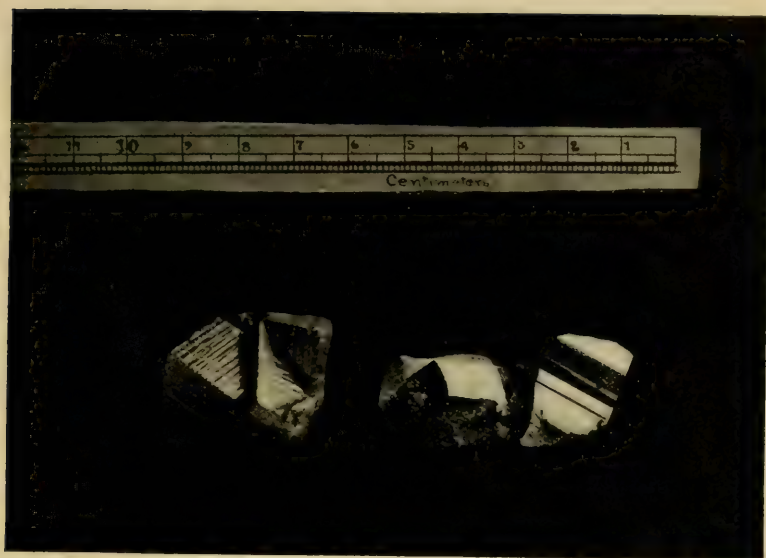
in much the same way as pyrite, with which it is frequently associated. Chalcopyrite is mined in Sweden, Spain, Sudbury Can., Montana and Utah. Handsome specimens associated with quartz have been found in New York at Ellenville, Ulster co.

Chalcopyrite is the principal source of copper.

Pyrite (iron pyrites) FeS_2

Pyrite, the isometric form of iron disulfid, contains 53.4% sulfur and 46.6% iron.

The crystals of pyrite are exceedingly interesting, showing as they do a diversity of form and a brilliancy of surface which render them objects of considerable beauty. Some of the forms of the pyritohedral group which are most frequently met with in pyrite are shown in fig. 168-72. Pl. 16₁ shows the striations so common in crystals of this species. Crystalline masses of varied form are quite frequent, producing botryoidal, globular, stalactitic and other shapes. The granular massive varieties are common. Pyrite has a brilliant metallic luster; its color is a pale brass-yellow somewhat lighter than that of chalcopyrite. Pyrite occurs in almost every variety of rock; the deposits in sedimentary rocks were probably formed by the precipitation of the included ferruginous matter from a hot aqueous solution in the presence of decaying vegetable and animal matter.



1 Pyrite, Gilpin county, Col.



2 Marcasite, Galena Ill.

Pyrite deposits are worked for the production of sulfuric acid in Louisa county, Va., in the Rio Tinto region of Spain and in various other localities including one at Hermon, St Lawrence

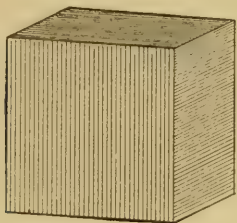


Fig. 168

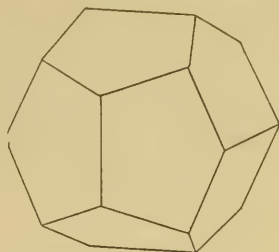


Fig. 169

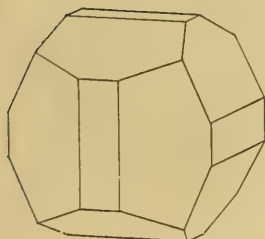


Fig. 170

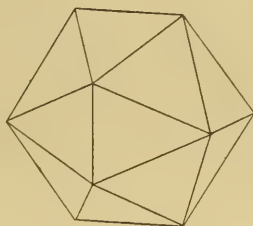
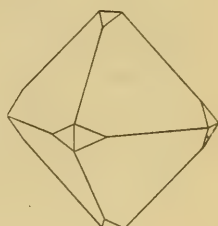
Fig. 171
Pyrite

Fig. 172

co. N. Y. Sometimes gold and copper contained in small quantities in pyrite are recovered.

Smaltite, chloanthite $(\text{CoNi})\text{As}_2$

The minerals of this group pass from one to the other by such insensible gradations that it is often impossible to separate them. Smaltite is essentially cobalt diarsenid containing 71.8% arsenic and 28.2% cobalt. Chloanthite is essentially nickel diarsenid and contains 71.9% arsenic and 28.1% nickel.

The crystals are similar to those of pyrite. The mineral usually occurs in tin-white to steel-gray metallic masses.

It occurs in veins with other ores of cobalt, nickel, copper and silver, notably in the Saxon and Bohemian localities. It is also found at Chatham Ct., Franklin N. J. and in California.

It is the main source of the cobalt products.

Cobaltite (cobalt glance) CoAsS

Cobaltite, the sulfarsenid of cobalt, contains 19.3% sulfur, 45.2% arsenic and 35.5% cobalt.

It resembles pyrite in crystallization and luster and is silver-white to gray in color.

Like smaltite it is a source of cobalt compounds.

Marcasite (white iron pyrites) FeS_2

Marcasite is the orthorhombic iron disulfid, and has the same composition as pyrite.

The dimorphism of iron disulfid is all the more interesting because pyrite represents an isomorphous group of sulfids and arsenids which crystallize in similar forms of the isometric system, and marcasite heads a similar isomorphous group crystallizing in closely related forms of the orthorhombic system.

Twins and crystalline aggregates are common, resembling spearheads, cockscombs, etc. often with radiated, stalactitic structure as in pl. 16₂. The color of marcasite is somewhat whiter than that of pyrite, which it closely resembles.

Marcasite occurs in Saxony, Bohemia and England, and in the United States, associated with sphalerite, at the zinc mines of Missouri, in Wisconsin and at Warwick, Orange co. N. Y.

It is used in the manufacture of sulfuric acid. It is also found in nodular concretions in the Tertiary and Cretaceous clays of Long Island and Staten Island.

Arsenopyrite (mispickel) FeAsS

Arsenopyrite is the sulfarsenid of iron and contains 46% arsenic, 34.3% iron and 19.7% sulfur.

Arsenopyrite crystallizes in the orthorhombic system in

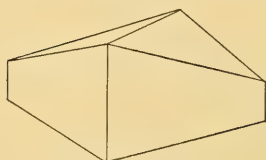
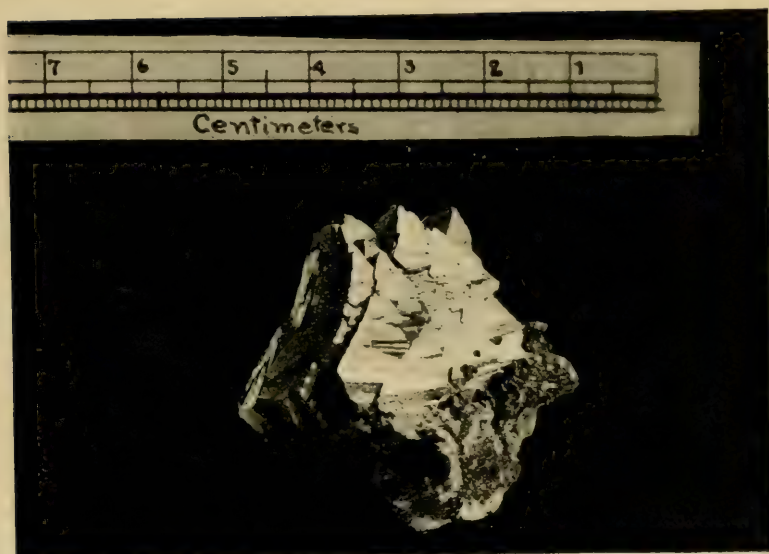


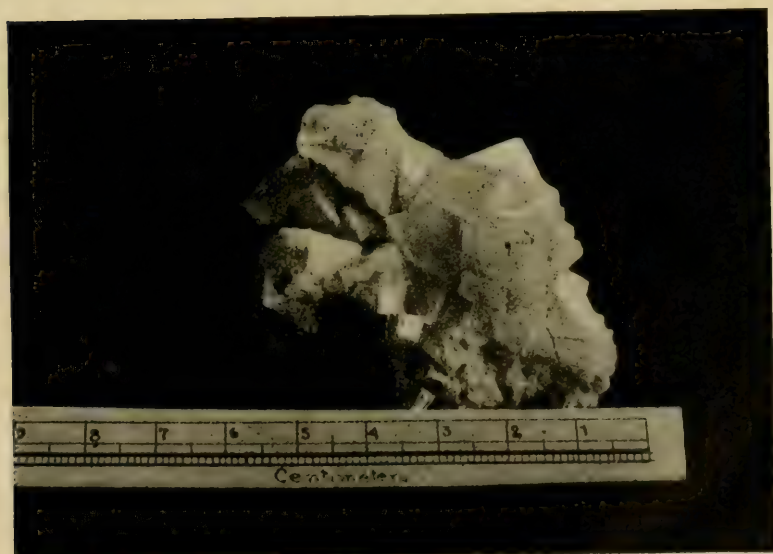
Fig. 173
Arsenopyrite

forms resembling marcasite. A common type of crystal is represented in fig. 173 and a characteristic grouping in pl. 17₁. Arsenopyrite commonly occurs in coarse to fine granular masses or disseminated grains. It is silver-white to gray, with a metallic luster.

Arsenopyrite is found principally in veins in crystalline rocks associated with other metallic sulfids and arsenids. The deposits of New South Wales, California and Alaska occasionally carry some gold. It is found in many European localities,



1 Arsenopyrite and dolomite, Freiberg, Saxony



2 Halite, Great Salt lake, Utah

in Canada, in parts of New England and in Orange and Putnam counties, N. Y.

Arsenopyrite is an ore of arsenic.

Sylvanite (graphic tellurium) $(\text{AuAg}) \text{Te}_2$

Sylvanite represents a group of gold and silver tellurids which has recently developed to considerable importance in the Cripple Creek district of Colorado. Sylvanite contains 62.1% tellurium, 24.5% gold and 13.4% silver.

It occurs in flat monoclinic crystals usually grouped in branching forms resembling written characters, it is silver-white to steel-gray in color, inclining to yellow, and has a brilliant metallic luster.

Sylvanite occurs in Transylvania, California and Boulder county, Col. where it is mined for gold.

SULFO-SALTS

SULFARSENITES, SULFANTIMONITES, ETC.

Bournonite (wheel ore) PbCuSbS_3

Bournonite is a sulfantimonite of lead and copper and contains 42.5% lead, 13% copper, 24.7% antimony and 19.8% sulfur.

The orthorhombic crystals are frequently twinned, producing the "cogwheel" forms from which the species derives its common name. It frequently occurs massive, granular or compact. The color is steel-gray to dark gray and the luster metallic.

Bournonite is found in Germany, Bohemia, Hungary, Cornwall, Mexico, Chile; also in Canada, Arizona, Arkansas and Colorado.

Pyrargyrite (dark ruby silver ore) Ag_3SbS_3

Pyrargyrite is a sulfantimonite of silver and contains 17.8% sulfur, 22.3% antimony and 59.9% silver.

Pyrargyrite crystallizes in the rhombohedral-hemimorphic group of the hexagonal system. The crystals are prismatic with rather flat terminations and are frequently twinned. It is translucent to opaque, of a deep red color by transmitted light and gives a purplish red streak. The luster is metallic to adamantine.

Pyrargyrite is found in several German localities, in Mexico and Chile; also in Idaho, Nevada, Colorado and other silver bearing regions of the western states.

It is mined for silver.

Proustite (light ruby silver ore) Ag_3AsS_3

Proustite is a sulfarsenite of silver and contains 19.4% sulfur, 15.2% arsenic and 65.4% silver.

Proustite closely resembles pyrargyrite in crystallization as well as in translucency. Its luster is adamantine rather than metallic and it differs from pyrargyrite in the color, which shades more toward scarlet. The streak is scarlet.

Proustite is found associated with pyrargyrite, the localities being essentially the same as for that species.

It is a source of silver.

Tetrahedrite (gray copper ore) $\text{Cu}_8\text{Sb}_2\text{S}_7$

Tetrahedrite is a sulfantimonite of copper and contains 23.1% sulfur, 24.8% antimony and 52.1% copper. Some of the antimony is usually replaced by arsenic, which causes it to merge gradually into tennantite, the sulfarsenite of silver.

Tetrahedrite crystallizes in the tetrahedral group of the isometric system. The crystals, two of the commonest types

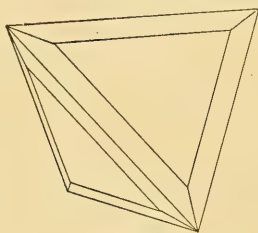


Fig. 174

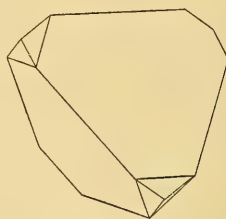


Fig. 175

Tetrahedrite

of which are shown in fig. 174, 175, are tetrahedral in habit. Massive forms are frequent. The color varies from a light steel-gray to an iron-black; the luster is metallic.

Tetrahedrite is commonly associated with chalcopyrite, massive varieties frequently forming intimate mechanical mixtures; crystals of tetrahedrite are often incrustated with chalcopyrite. It is also associated with several other metallic sulfids. It is found in Europe, South America, Mexico, Nevada and Colorado.

Stephanite (brittle silver ore) Ag_5SbS_4

Stephanite is a sulfantimonite of silver containing 16.3% sulfur, 15.2% antimony and 68.5% silver.

Orthorhombic crystals in short prismatic and tabular forms are frequently found. The mineral usually occurs in fine grained masses of an iron-black color and metallic luster. Also in disseminated grains.

Stephanite occurs in veins with other silver ores, the principal localities being those mentioned under argentite, pyrrargyrite, etc.

Enargite Cu_3AsS_4

Enargite is a sulfarsenite of copper containing 32.6% sulfur, 19.1% arsenic and 48.3% copper.

Orthorhombic crystals are sometimes met with; these are prismatic in habit and striated parallel to the vertical axis. Enargite commonly occurs in columnar or granular masses. It is black in color and has a metallic luster.

Enargite is found associated with other copper minerals in Chile, Peru and Mexico; also in South Carolina, Colorado, Utah, California and in the Tintic district of Montana.

It is an ore of copper.

HALOIDS**CHLORIDS, BROMIDS, IODIDS, FLUORIDS****Halite (rock salt) NaCl**

Halite or common salt is the chlorid of sodium and contains 39.4% chlorin and 60.6% sodium. It seldom occurs perfectly pure but is commonly mixed with calcium sulfate, calcium chlorid, magnesium chlorid and magnesium sulfate.

Halite is isometric and usually crystallizes in cubes (pl. 17₂), which often show distortion and cavernous faces, as in fig. 176. Masses with perfect cubic cleavage are common as well as a fibrous variety which is said to be

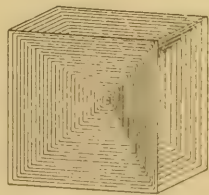


Fig. 176
Halite

pseudomorphous after fibrous gypsum. Halite has a vitreous luster and when pure is colorless and transparent; yellow, red, brown, blue and purple shades are due to impurities, as is also the translucency accompanying these variations in color. It has a characteristic saline taste.

Salt is of wide distribution and frequently occurs in beds of sufficient size to constitute a true rock mass. These deposits, which are found interstratified with rocks of all geologic horizons, have been formed by gradual evaporation from bodies of water which have been cut off from the main body of the ocean, or which, as in the case of Great Salt lake and the Dead sea, have been concentrated through lack of an outlet. The mineral matter is crystallized out in inverse ratio to its solubility, the less soluble minerals, such as gypsum, forming prior to the more soluble ones such as salt. This process is still taking place in many parts of the world.

Halite is of such universal occurrence that a list of its localities would include almost every civilized country. In the United States extensive and valuable deposits of salt are found in central and western New York, in Ohio, Michigan, West Virginia, Kansas, Louisiana, Nevada, Utah, Arizona and California. Salt springs and wells abound in the neighborhood of the salt deposits and these as well as the waters of salt lakes and sea waters are used as sources of the commercial product.

Halite is used to form a glaze on pottery and in many chemical and metallurgic industries as well as for the familiar culinary and preservative purposes.

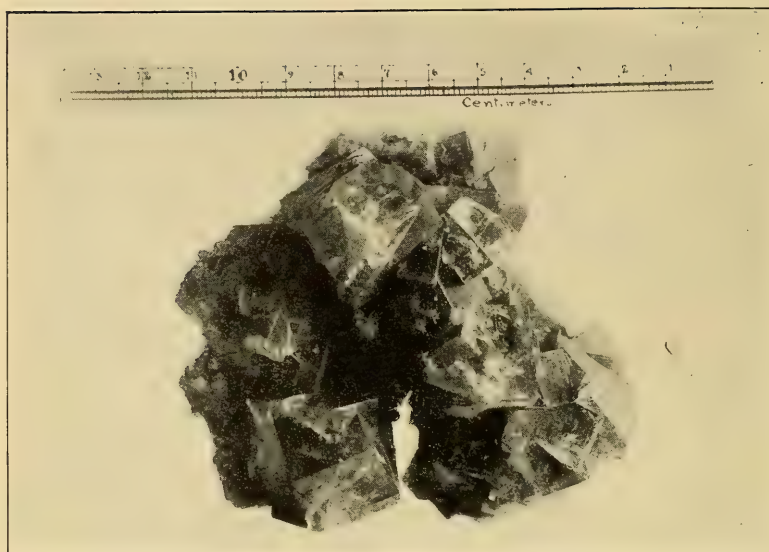
Cerargyrite (horn silver) AgCl

Cerargyrite, the chlorid of silver, is composed of 24.7% chlorine and 75.3% silver.

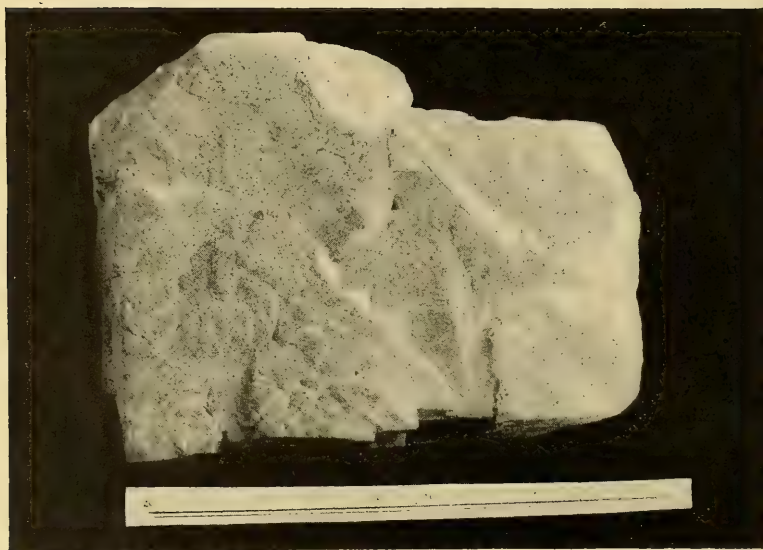
Isometric crystals of a cubic habit are quite rare, the mineral usually occurring in massive crusts or coatings of a grayish green to violet color and waxy or resinous luster resembling horn or wax. It is extremely sectile and turns violet-brown on being exposed to the light.

Cerargyrite probably results from precipitation from silver charged solutions in contact with the chlorids contained in surface waters. It usually occurs near the top of veins in clay slate, associated with other ores of silver. Cerargyrite is found extensively in Peru, Chile and Mexico; it also forms part of the mineral wealth of Colorado, Nevada, Idaho and Utah.

It is mined for silver.



1 Fluorite, Cumberland, England



2 Fluorite, Macomb N. Y.

Fluorite (fluor spar) CaF_2

Fluorite is the fluorid of calcium and contains 48.9% fluorin and 51.1% calcium.

The isometric crystals of fluorite exhibit many interesting forms, some of which are shown in fig. 177-79. Penetration

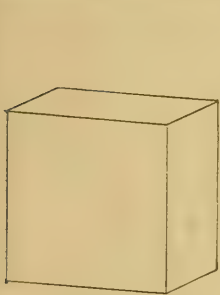


Fig. 177

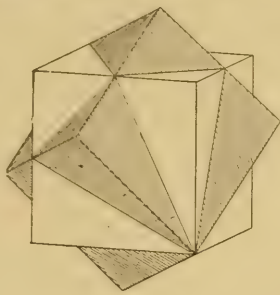
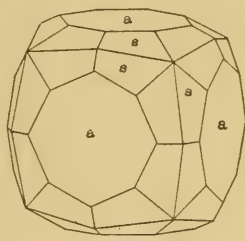
Fig. 178
Fluorite

Fig. 179

twins are quite common (pl. 18₁). The crystals are vitreous, transparent and of a great variety of colors, white, yellow, greenish blue, purple and green being most common; white, pink, red, sky-blue and other colored varieties are often found. Massive varieties sometimes show irregular banding of different colors. Granular and fibrous occurrences are less frequent. All varieties are characterized by perfect cleavage parallel to the octahedron, which can be frequently traced in the crystallized specimens, as in pl. 18₂.

Fluorite is found in beds, or more often in veins, in gneiss, slate, limestone and sandstone; it frequently occurs as the gangue of metallic minerals, notably lead ores. Fluorite occurs in many parts of England and Saxony; also in Rosiclare Ill. where it is mined in large quantities, in Jefferson and St Lawrence counties, N. Y. and in several other states.

Fluorite is used as a flux in some metallurgic processes, also in the production of opalescent glass, enameled cooking ware and hydrofluoric acid.

Cryolite Na_3AlF_6

Cryolite is a fluorid of sodium and aluminium, containing 54.4% fluorin, 12.8% aluminium and 32.8% sodium.

The monoclinic crystals of cryolite frequently present a cubic aspect due to the fact that the β angle is nearly 90° and the

a and *b* axes almost equal. Parallel groupings are common as well as massive and columnar forms. The cleavage is nearly cubic in angle. Cryolite is transparent to translucent; colorless or white, often reddish, brownish or black owing to small amounts of iron, and has a vitreous to greasy luster. The German name *Eisstein* (ice-stone) suggests its resemblance to ice. It is quite soft ($H=2.5$) and is readily melted in the flame of a candle.

The principal locality for cryolite is Ivigtut in west Greenland, where it is found in a vein in gray gneiss.

It is used in several chemical processes, notably in the manufacture of aluminium.

Atacamite $\text{Cu}_2\text{ClH}_3\text{O}_3$

Atacamite is a hydrated oxychlorid of copper containing 16.6% chlorin, 14.9% copper, 55.8% copper oxid and 12.7% water.

Atacamite occurs in orthorhombic prismatic crystals, vertically striated. It is more commonly found in confused crystalline aggregates and fibrous or granular massive forms. The luster is adamantine to vitreous and the color bright to dark green.

Atacamite takes its name from the Atacama desert in northern Chile where it is found associated with other copper ores; it is also found in Bolivia, South Australia, Cornwall and Arizona.

It is an ore of copper.

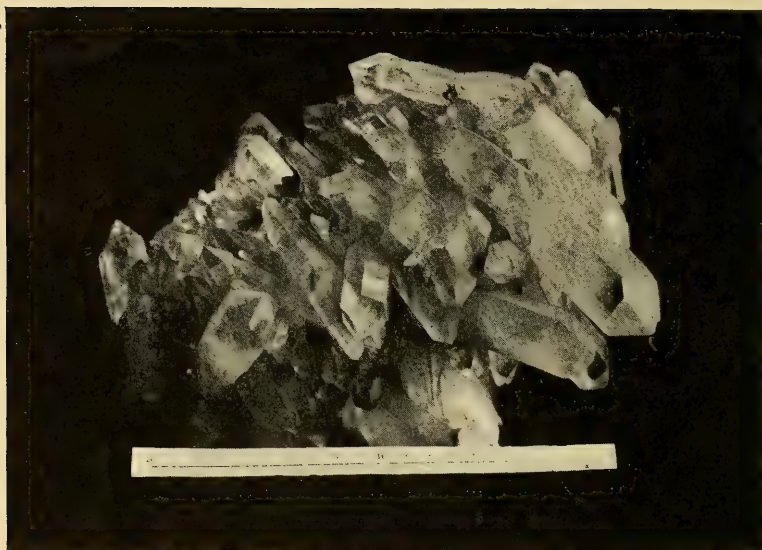
OXIDS

OXID OF SILICON

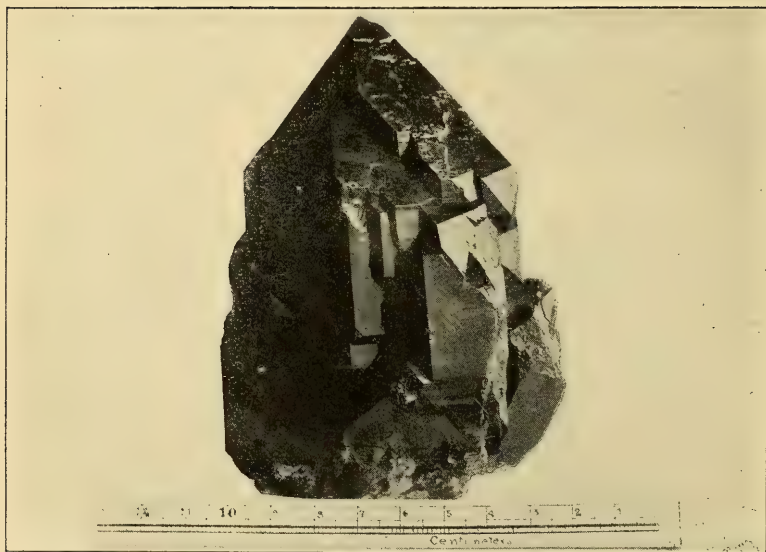
Quartz SiO_2

Quartz is pure silica or silicon dioxid (53.3% oxygen and 46.7% silicon). It is often colored by small amounts of iron oxid, manganese, titanium, carbon, etc.

Quartz crystallizes in the rhombohedral-trapezohedral group of the hexagonal system; the crystals are commonly prismatic with the prism faces striated parallel to the basal plane and are terminated by one or both rhombohedrons together with other modifications characteristic of the group. Distortion gives rise to flat and unequally developed forms of great variety as well as acicular, tapering and twisted individuals. Grouping of crystals in parallel position, "scepter," "phantom," and capped



1 Quartz, Crystal mountain, Ark.



2 Quartz (smoky), St Gothard, Switzerland

forms are of particular interest from a crystallographic point of view. Twinning occurs quite frequently. Massive forms occur in great variety with granular mammillary stalactite and concretionary structure, plane or banded.

Quartz has a vitreous luster in the crystallized varieties which passes, in the massive forms, to greasy, splendid or dull.

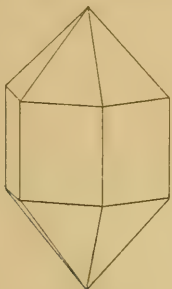


Fig. 180

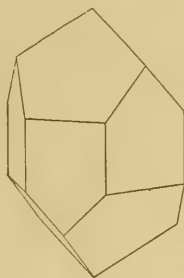


Fig. 181

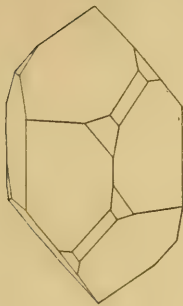


Fig. 182

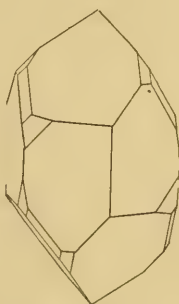


Fig. 183

Quartz

When pure, quartz is transparent and colorless with a white streak; various shades of yellow, red, brown, green, amethyst and black are due to slight impurities.

A—CRYSTALLINE VARIETIES

Rock crystal. Pure, colorless

Amethyst. Purple to violet. Color probably due to manganese

Rose quartz. Pink to rose. Colored by titanium

Smoky quartz. Smoky brown to black. Color probably due to carbon

Milky quartz. Translucent white. Usually massive

Ferruginous quartz. Opaque brown to red. Colored by iron

Aventurin. Spangled with scales of mica, hematite etc.

B—CRYPTOCRYSTALLINE VARIETIES

Chalcedony. Mammillary. Uniform in tint

Carnelian. A clear, red chalcedony

Chrysoprase. Apple green. Color due to nickel

Prase. Dull, leek-green

Agate. A variegated chalcedony. Colors are banded, irregularly clouded or in mosslike dendritic forms

Onyx. Parallel layers light and dark

Jasper. Impure, opaque.

Quartz occurs as a constituent of many rocks such as granite, gneiss, quartz porphyry, syenite, sandstone, etc. and as a vein mineral in rocks of all geologic horizons. Its distribution is so extensive as to preclude its limitation to any given area. Quartz rocks are extensively used for building stone; chalcedonic varieties are often polished for ornamental objects and massive varieties are ground and used in the manufacture of sandpaper, glass and porcelain and as an acid flux in some metallurgic processes.

Opal $\text{SiO}_2 \cdot n\text{H}_2\text{O}$

Like quartz, opal is composed of silica or silicon dioxid, but contains from 5% to 12% water.

Opal shows no evidences of crystallization and is therefore considered amorphous. It occurs in transparent to translucent milky white or red masses and veins, often characterized by internal reflections and rich play of colors; in waxy masses yellow, red, brown, green, gray or blue in color; in opaque, porous, brittle stalactitic masses deposited by geysers and hot springs and in earthy varieties.

VARIETIES

Precious opal. Exhibits play of color. Used as a gem

Fire opal. Red, firelike reflections

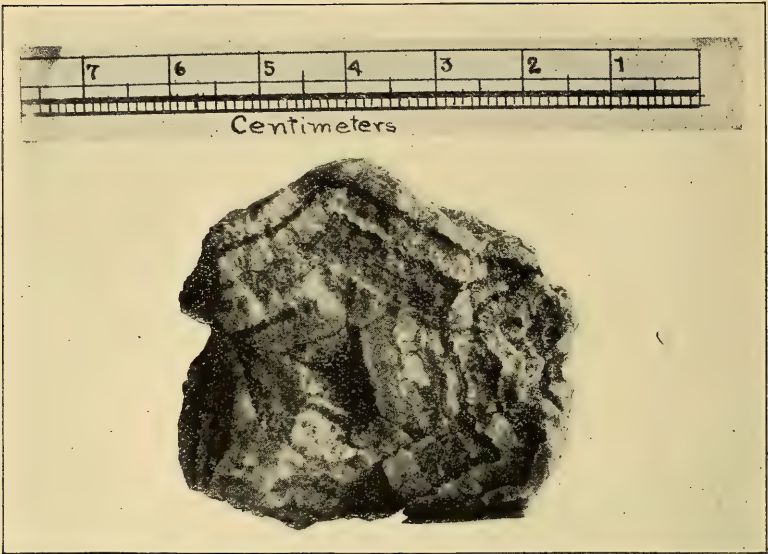
Common or semiopal. In part translucent with greasy luster

Wood opal. Pseudomorphous after wood

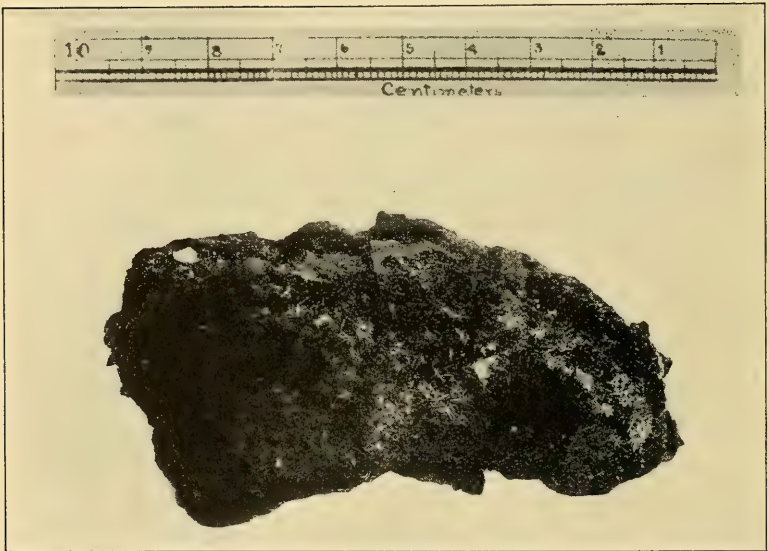
Hyalite. Colorless, transparent, droplike masses

Geyserite. Porous opal, deposited from hot water carrying silica

Tripolite. Massive, chalklike silica composed of the remains of diotomes.



1 Quartz (agate), Wyoming



2 Cuprite (chalcotrichite), Morenci Ariz.

Opal occurs in cavities and fissures in igneous rocks, as concretions in limestones, as sinter in the vicinity of geysers, hot springs, etc. The precious variety is found in Hungary, Australia, Mexico and in Washington and Idaho.

Precious opal is highly valued as a gem. The chalky variety is used for polishing and washing purposes, in the manufacture of dynamite and in the preparation of a soluble glass.

OXIDS OF METALS

Cuprite (red copper ore) Cu_2O

Cuprite is the oxid of copper and contains 11.2% oxygen and 88.8% copper.

Crystals of cuprite (fig. 184, 185) are isometric, the prevailing

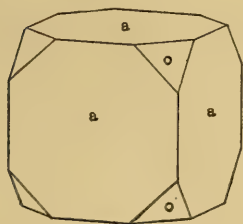


Fig. 184

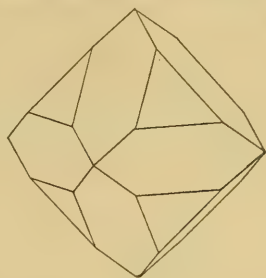


Fig. 185

Cuprite

forms being the cube, octahedron and dodecahedron, often highly modified; in the variety chalcotrichite the cube crystals are distorted to such an extent as to produce hairlike forms (pl. 20₂). Massive, granular and earthy forms are common. The luster of cuprite is submetallic or adamantine to earthy and the color varies from a dark red which is nearly black to a vermilion or scarlet, seen in some of the massive varieties. It is transparent to opaque.

Cuprite results from the oxidation of the sulfids of copper and is found associated with other copper minerals and with limonite. It occurs in fine crystals in the Cornwall mines and is found in considerable deposits in Chile, Bolivia, Peru, the Lake Superior region and Arizona.

It is a useful copper ore.

Zincite (red zinc ore) ZnO

This oxid of zinc contains 19.7% oxygen and 80.3% zinc; it usually carries some manganese.

The natural crystals, which are rare, have been referred to the hemimorphic group of the hexagonal system. Zincite ordinarily occurs in deep red to brick-red adamantine masses with a foliated or granular structure or as coarse grains disseminated through the matrix. It has a subadamantine luster and is translucent.

Zincite occurs in the vicinity of Franklin N. J. associated with the minerals characteristic of that locality and is mined with the associate minerals for the zinc which it contains.

Corundum (emery) Al_2O_3

Corundum is alumina, or sesquioxid of aluminium, and contains 47.1% oxygen and 52.9% aluminium; massive emery contains more or less iron oxid as an impurity.

Crystals of corundum are rhombohedral (fig. 186, 187); rough



Fig. 186

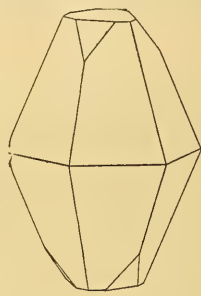


Fig. 187

Corundum

and rounded forms are characteristic, as well as twinning, which is indicated by laminated structure and intersecting striations. With the exception of the diamond, corundum is the hardest substance known.

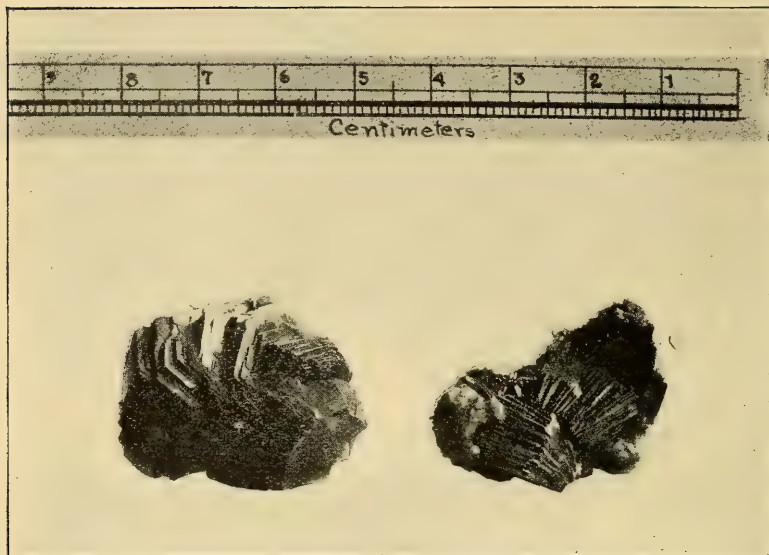
The precious varieties known as sapphire and ruby are transparent or translucent, with vitreous to adamantine luster, and abound in fine colors.

The gems cut from these varieties are:

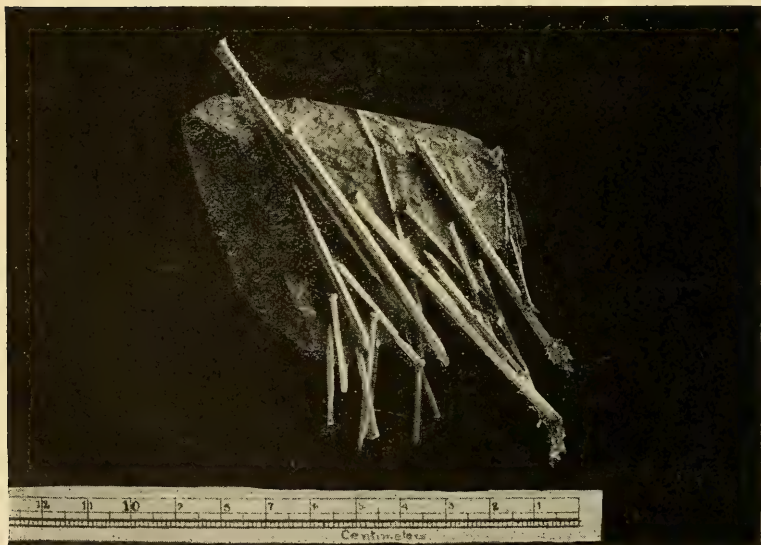
Sapphire. Blue in color

Oriental ruby. A rich red





1 Hematite (Eisenrosen), St Gothard, Switzerland



2 Magnetite (lodestone), Magnét Cove Ark.

Oriental topaz. Yellow

Oriental emerald. Green

Oriental amethyst. Purple

An opaque variety of corundum occurs in coarse nodular crystals with a marked rhombohedral parting and of a dull blue, gray, brown or black color.

The variety known as emery is granular in texture, of great toughness and black or grayish black in color. It is commonly intermingled with hematite or magnetite. This variety, which is of great value as an abrasive, is found in a number of grades, classed on the relative coarseness of the corundum crystals or grains.

The gem varieties of corundum are found in the gravel of river beds in Upper Burma and Ceylon; some handsome gems have been obtained from Montana and North Carolina.

Corundum occurs in many crystalline rocks associated with minerals of the chlorite group, tourmalin, spinel, cyanite, etc. and has been observed in some of the younger volcanic rocks. It is mined for emery in the island of Naxos, in Asia Minor, and in the United States at Chester Mass., in Westchester county, N. Y. and elsewhere.

Hematite (specular iron) Fe_2O_3

Hematite is the sesquioxid of iron and contains 30% oxygen and 70% iron.

Hematite crystallizes in the rhombohedral group of the hexagonal system. The crystals are commonly thick or tabular in habit (fig. 188) as distinct from the tapering forms of corundum, and are often reduced to thin plates which in some varieties group themselves in rosettes (eisenrosen pl. 21.). Massive forms in compact columnar, radiated and kidney-shaped masses pass into loose earthy varieties, containing more or less clay. The luster of hematite varies with its form from a splendid metallic, in the crystallized varieties, to dull in the ocherous and argillaceous hematite; the color also varies from iron-black to red. The streak is red in all varieties.

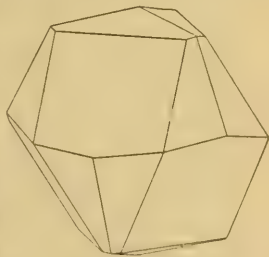


Fig. 188
Hematite

Hematite occurs in rocks of all geologic horizons. It is widely distributed and the numerous foreign localities afford beautifully crystallized specimens. In the United States vast beds of hematite are found in the Archaean rocks of northern Michigan, northern Wisconsin, Minnesota, Missouri, and in Jefferson and St Lawrence counties of northern New York; also in the Clinton group of the Upper Silurian in New York and Pennsylvania.¹

Hematite constitutes the chief source of iron; the earthy variety is ground for paint.

Ilmenite or menaccanite (titanic iron ore) $(\text{Fe,Ti})_2\text{O}_3$

Ilmenite is an oxid of iron and titanium containing 31.6% oxygen, 31.6% titanium and 36.8% iron. The crystals, which are trihombobedral, somewhat resemble those of hematite in habit (fig. 189). Ilmenite commonly occurs in iron-black plates and masses of submetallic luster, also in embedded grains or as loose sand.

Ilmenite is found in many igneous rocks notably in gabbros and diorites; it is sometimes altered to limonite and titanite. In addition to several European localities ilmenite is found in the town of Warwick, Orange co. N. Y. and at Litchfield Ct.

The large amount of fuel required to reduce this mineral renders it, in most cases, undesirable as an ore of iron. It is, however, used as a lining in furnaces.

Spinel $\text{MgO}.\text{Al}_2\text{O}_3$

Spinel, the magnesium aluminate, contains 71.8% alumina and 28.2% magnesia. These two components may be replaced in part by ferrous and ferric iron, manganese and chromium.

The crystals of spinel are isometric, usually the octahedron or the octahedron modified, and are frequently twinned (fig. 190). The luster is vitreous to dull and the color varies from red to blue, green, yellow and black. A transparent variety called ruby spinel is transparent to translucent and often of a rich red color. This constitutes the gem known as

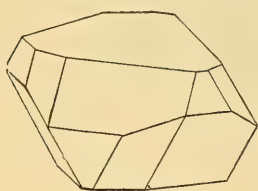


Fig. 189
Ilmenite

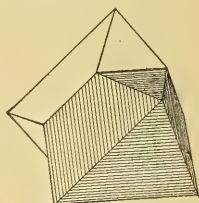


Fig. 190
Spinel

¹N. Y. state mus. Bul. 7. 1889.

spinel ruby or balas ruby, which often rivals the oriental ruby in color and fire.

Spinel occurs in limestone, gneiss, serpentine and other metamorphic rocks. Spinel ruby is abundant in Ceylon and Burma and has been obtained from Hamburg N. J. and Orange county, N. Y. Crystals of spinel are found in many parts of North Carolina and Massachusetts and near the boundary line between New York and New Jersey.

Magnetite (magnetic iron ore) $\text{FeO} \cdot \text{Fe}_2\text{O}_3$

Magnetite is composed of iron sesquioxide and iron protoxide and contains 72.4% iron and 27.6% oxygen.

Magnetite crystallizes in isometric forms closely resembling those of spinel. Parting parallel to the octahedron is often developed (*see* specimen from Mineville N. Y. in N. Y. state mus. collection). Massive varieties have laminated, coarse or fine granular and compact structure (pl. 4₂). Magnetite has a metallic or submetallic luster, is black in color and is strongly magnetic. A variety known as lodestone is a natural magnet (pl. 21₂).

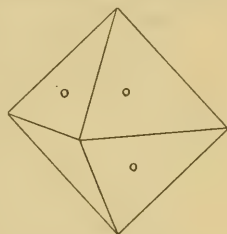


Fig. 191
Magnetite

Magnetite occurs mostly in crystalline rocks and is of universal distribution. Extensive beds are found in the Archæan formation of northern New York and in the Adirondack region, as well as in Saratoga, Herkimer, Orange and Putnam counties of the same state,¹ the former deposits being to a considerable extent titaniferous.

Magnetite is extensively mined for iron.

Franklinite $(\text{FeMnZn})\text{O} \cdot (\text{FeMn})_2\text{O}_3$

Franklinite is an iron, zinc and manganese ferrate and manganate of rather complicated formula and varying relative quantities.

The isometric crystals of franklinite are octahedral in habit and are generally characterized by rounded edges, otherwise they resemble those of magnetite. Franklinite also occurs in rounded grains and in compact masses. In color and luster it

¹N. Y. state mus. Bul. 7. 1889.

closely resembles magnetite and is chiefly distinguished by its slight tendency to attract the magnet and by its characteristic association with zincite and willemite at Franklin and Ogdensburg N. J. its most notable localities.

It is used at Franklin with other ores for the production of zinc and of an alloy of iron and manganese known as spiegeleisen.

Chromite (chromic iron) $\text{FeO.Cr}_2\text{O}_3$

Chromite, the iron chromate, contains 68% chromium sesquioxid and 32% iron protoxid.

Chromite is rarely found in small octahedral crystals. It commonly occurs as a black massive mineral resembling massive magnetite, sometimes in disseminated grains and sand. It is, in some instances, feebly magnetic.

It occurs in veins or embedded masses in serpentine and may often be recognized by its association with that mineral.

Turkey and New Caledonia furnish much of the chromite now used. A somewhat lower grade ore is found in extensive deposits in California.

Chromium extracted from chromite is used in the production of several pigments, in the manufacture of bichromate of potash for calico printing and for chrome steel.

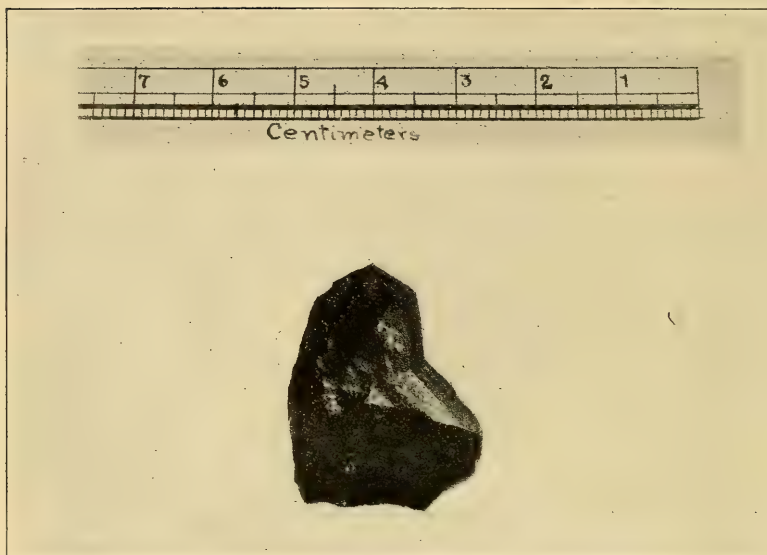
Chrysoberyl $\text{BeO.Al}_2\text{O}_3$

Chrysoberyl is the aluminate of beryllium and contains 80.2% alumina and 19.8% glucina.

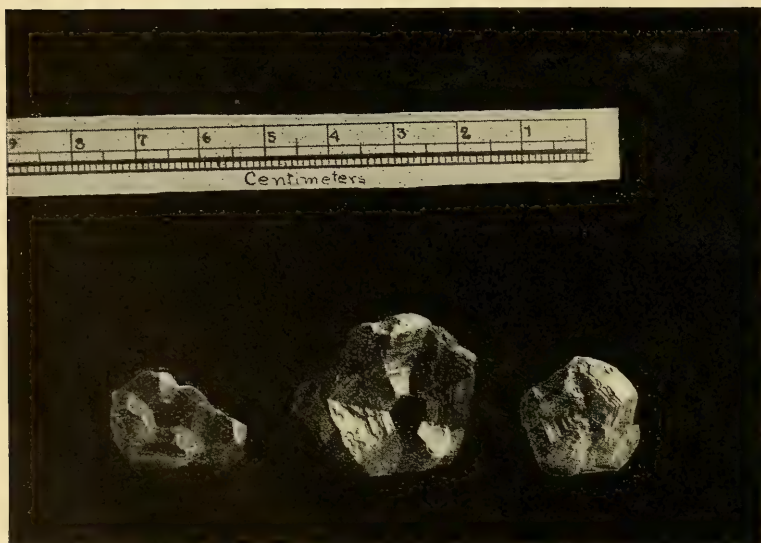
The crystals of chrysoberyl, which are orthorhombic, are commonly twinned producing pseudohexagonal shapes which sometimes show reentrant angles. The crystals are generally tabular in habit with intersecting, featherlike striation due to repeated twinning. Chrysoberyl is transparent to translucent, of a vitreous luster and of various colors from a pale yellowish green to emerald-green. The variety alexandrite is of an emerald-green color by reflected light which, however, changes to a columbine-red by transmitted light.

Brazil, Ceylon, Moravia and the Ural mountains of Russia produce chrysoberyl. It has been found at Haddam Ct. and at Greenfield N. Y.

Chrysoberyl is used as a gem, the varieties alexandrite and cat's eye being specially prized.



1 Cassiterite, Schlaggenwald, Bohemia



2 Rutile, Magnet Cove Ark.

Cassiterite (stream tin) SnO_2

Cassiterite is the dioxid of tin containing 21.4% oxygen and 78.6% tin.

Tetragonal crystals of the general type shown in fig. 192 are terminated with a low pyramid. Forms of prismatic habit with steeper and more complicated terminations are also characteristic, and twins similar to the form shown in pl. 22₁ are quite common. Reniform masses and rounded pebbles with fibrous radiated structure (stream tin) are of common occurrence. The luster of cassiterite is adamantine and in the case of crystallized varieties is usually splendid; the color is brown or black, sometimes red, grey or yellow, and the streak is brown.

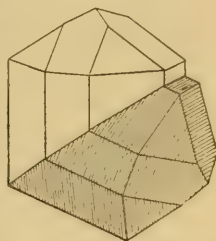


Fig. 192
Cassiterite

Cassiterite occurs in veins traversing granite, gneiss and other igneous and metamorphic rocks. It is found abundantly in Cornwall and other parts of England, in Bohemia, Saxony, East Indies, Australia, Bolivia and Mexico; also in the United States in South Dakota, California and other states.

Cassiterite is the sole source of tin.

Rutile (nigrin) TiO_2

Rutile is the dioxid of titanium and contains 40% oxygen and 60% titanium.

In crystallization rutile closely resembles cassiterite (fig. 193). The crystals are prismatic in habit, often passing into acicular and hairlike forms which are vertically striated and are sometimes included in quartz and other minerals. Twinning, resulting in knee-jointed crystals and rosettes (pl. 22₂), is quite common. Rutile is occasionally found in compact masses which carry some iron. The luster of rutile is rather more brilliant and metallic than cassiterite and may be described as metallic-adamantine;

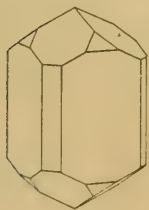


Fig. 193

in color it varies from brownish red to nearly black and when seen by transmitted light in transparent varieties it is deep red.

Rutile occurs in granite, gneiss, syenite, mica, slate and sometimes in the limestones; it is frequently embedded in other

minerals and is of common occurrence as grains or fragments in many gold-bearing sands. It is found in many parts of Europe and also in Maine and Georgia, at Magnet Cove Ark. and in Orange county, N. Y.

Rutile is chiefly used to color porcelain and may serve as a source of titanium.

Octahedrite. Octahedrite is a tetragonal mineral of the same composition as rutile but differs slightly from it in crystallization.

Brookite. Brookite is an orthorhombic form of titanium dioxid closely related to the two foregoing minerals.

Pyrolusite MnO_2

Pyrolusite is the dioxid of manganese and contains 36.8% oxygen and 63.2% manganese.

Pyrolusite commonly occurs in columnar masses which frequently radiate from a center; also in fine grained massive stalactitic and dendritic forms (pl. 8₂), in layers interposed with psilomelane and in velvety, reniform crusts. It is black in color and so soft (H-1-2.5) that it leaves a black mark on paper. The luster is metallic or dull.

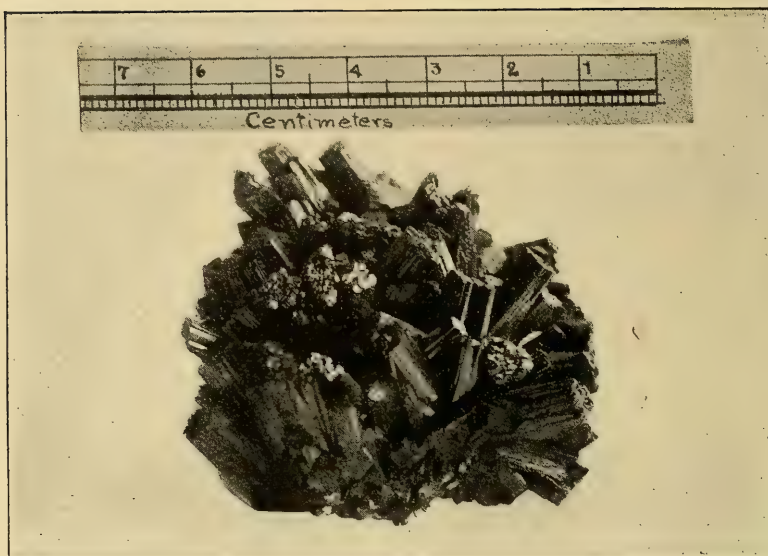
Pyrolusite occurs associated with psilomelane, hematite, limonite and manganite. It is found in central Europe, India, Australia and Cuba; deposits occur in the United States in Virginia, Georgia, Arkansas, California, Vermont and North Carolina; New Brunswick and Nova Scotia furnish a high grade material.

Pyrolusite is used in the manufacture of various useful alloys, as an oxidizing agent in the manufacture of chlorin, bromin and disinfectants and in calico printing, glass coloring, etc.

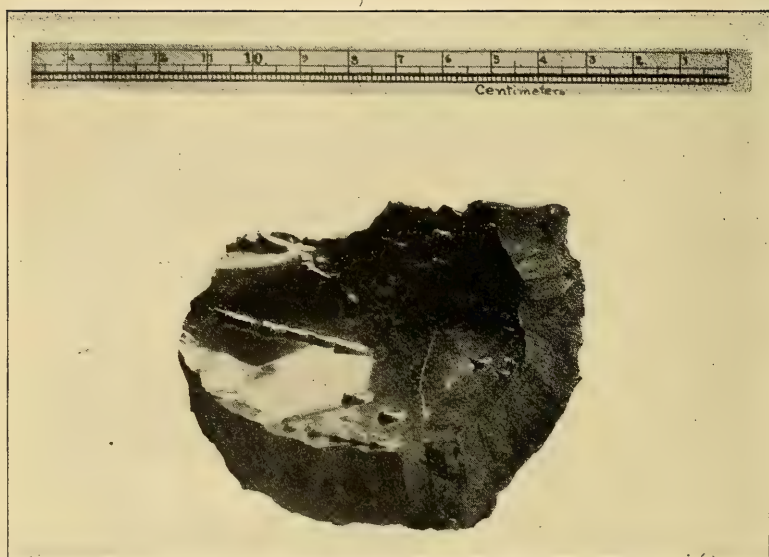
Göthite $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$

Göthite is a hydrated sesquioxid of iron and contains 27% oxygen, 62.9% iron and 10.1% water.

The orthorhombic crystals of göthite are prismatic in habit, striated in the direction of the vertical axis and often flattened in the direction of the brachyaxis into scales. Needlelike crystals grouped in radiating or parallel position pass into massive featherlike structure and reniform and stalactitic forms.



1 Manganite, Ilfeld, Hartz, Germany



2 Limonite, Richmond Mass.

The luster is adamantine and the color yellowish, reddish and blackish brown.

Göthite occurs with other oxids of iron specially hematite and limonite and is classed commercially with limonite under the name of "brown hematite." It is an ore of iron.

Manganite $\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$

Manganite is a hydrated sesquioxid of manganese containing 27.3% oxygen, 62.4% manganese and 10.3% water.

Manganite occurs in orthorhombic crystals usually prismatic with deeply striated or grooved surfaces; these are frequently grouped in bundles giving the appearance of sheaves of rods (pl. 23₁). It is rarely found in massive granular or stalactitic forms. The luster of manganite is submetallic and the color gray to black.

Manganite occurs associated with other manganese minerals which commonly result from its alteration.

For uses see Pyrolusite.

Limonite (brown hematite) $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$

Limonite is a hydrated sesquioxid of iron differing from göthite in the relative amount of iron sesquioxid and water; it contains 25.7% oxygen, 59.8% iron and 14.5% water. The ochereous varieties often contain clay or sand.

Limonite does not occur crystallized. It is commonly found in mammillary, botryoidal or stalactitic masses grading into loose and porous bog ore and earthy and concretionary masses.

The compact variety has a black varnishlike surface and fibrous radiated structure (pl. 23₂). The forms of looser structure are characterized by a dull luster and range in color from brown to yellow. The streak of limonite is brown.

Limonite is formed from the decomposition or alteration of other minerals containing iron; thus the bog ore is deposited in a marshy place by streams carrying iron in solution which is oxidized, sinks to the bottom, and in time by the combined action of heat and pressure is transformed into a bed of limonite.

Limonite is found in Bavaria and other parts of Germany, in Scotland, Sweden, etc. It is mined from large deposits in Virginia, Alabama, Pennsylvania, Michigan, Tennessee and

Georgia and in Dutchess and Columbia counties, N. Y.¹ It is also found in Richmond co. N. Y.

Limonite is an abundant but low grade ore of iron; the ochreous varieties are ground for paint.

Bauxite $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$

Bauxite is a hydrous aluminium sesquioxide containing 73.9% alumina and 26.1% water. The aluminium is often replaced in part by iron. Bauxite occurs in disseminated, rounded grains and in oolitic, spongy or claylike masses; sometimes fine grained compact. The luster is dull and the color varies from white when pure to red, yellow, and brown for the iron-bearing varieties.

Bauxite is found at Baux and elsewhere in France; also in Arkansas, Alabama and Georgia. It is the chief source of aluminium and is used in the manufacture of alum.

Brucite $\text{MgO} \cdot \text{H}_2\text{O}$

Brucite is the magnesium hydrate and contains 69% magnesia and 31% water.

The crystals are rhombohedral and tabular in habit. The mineral is of more frequent occurrence in translucent foliated masses and in fibrous forms. The luster is pearly or waxy to vitreous and the color white, gray, bluish or green.

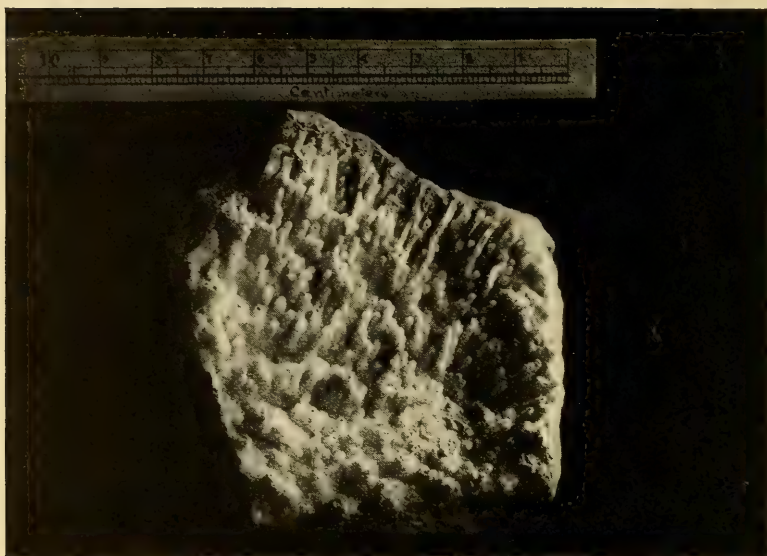
Brucite occurs in serpentine and limestone associated with other magnesium minerals. It is found at Hoboken N. J., at Brewster, Putnam co. and in Richmond and Westchester counties N. Y.; also at Texas Pa.

Gibbsite $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$

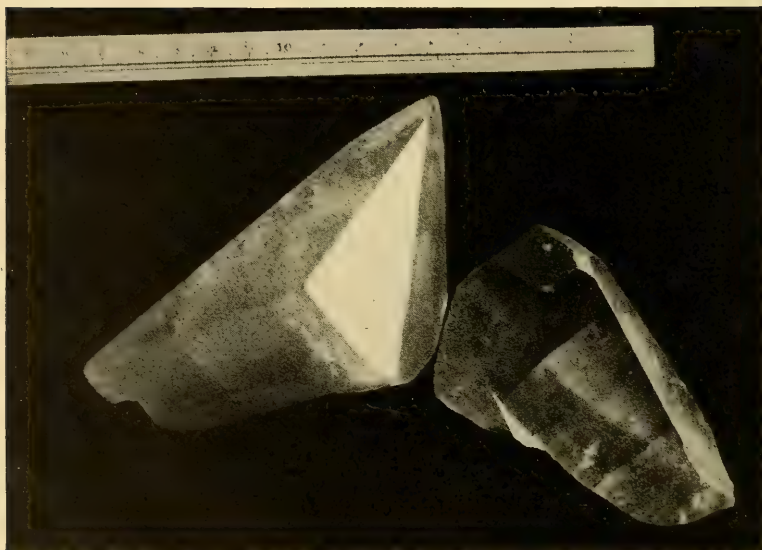
Gibbsite is an aluminium hydrate containing 65.4% alumina and 34.6% water.

It is rarely found in six sided monoclinic crystals, but usually occurs in mammillary crusts and stalactitic shapes (pl. 24₁) which sometimes show an ill defined, fibrous, internal structure. The color is commonly white or nearly white but may be grayish, greenish, reddish or yellow; the luster is subvitreous. The mineral is found in small deposits, often associated with limon-

¹N. Y. state mus. Bul. 7. 1889.



1 Gibbsite, Richmond Mass.



2 Calcite, Joplin Mo.

ite, at Richmond Mass., with the bauxite of Georgia and Alabama, and in Dutchess and Orange counties, N. Y.

It is an ore of aluminium but has not been found in sufficient quantities to render it of much importance.

Psilomelane (black hematite)

Psilomelane is a hydrous manganese manganate of somewhat doubtful composition and usually very impure.

Psilomelane does not occur crystallized. It is found in black or dark gray, botryoidal, reniform or stalactitic masses with a submetallic or dull luster.

It is commonly associated with pyrolusite in alternate layers and is found in many localities given for the latter mineral. It is applied to the same uses as pyrolusite.

OXYGEN SALTS

CARBONATES

The anhydrous carbonates form two distinct isomorphous groups, one of which is distinguished by rhombohedral crystalline forms of singularly close relation in the various species which form the group; this is named from its most prominent member the calcite group. Similarly the orthorhombic forms of aragonite are closely related crystallographically to those of the other carbonates in the aragonite group.

Calcite (calcareous spar, limestone) CaCo_3

Calcite is the carbonate of calcium and contains 44% carbon dioxid and 56% lime.

Calcite crystallizes in the rhombohedral class of the hexagonal system, the great variety and beauty of its crystals making it an object of interesting study to the novice as well as to the trained mineralogist. The unit rhombohedron shown in fig. 194 is an important form both because it is prominent in many varieties and because the perfect and strongly marked cleavage of calcite takes place in planes parallel to the faces of the unit rhombohedron. Many varieties are scalenohedral in habit, crystallizing in forms similar to those shown in fig. 195-97. The name "dog tooth spar" is given to this type, a specimen of which is shown in pl. 24. A flat rhombohedron (fig. 198) is prominent in the variety known as "nail head spar."

A steep rhombohedron also occurs modified in many ways, also crystals of prismatic habit (pl. 25₁). Twins are of common occurrence and are of several forms one of which is shown in fig. 199. Calcite also occurs massive with easy rhombo-

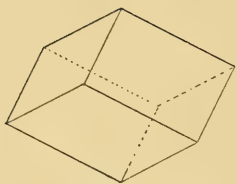


Fig. 194

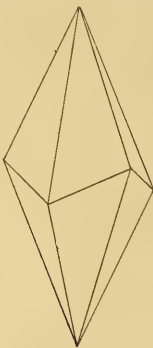


Fig. 195

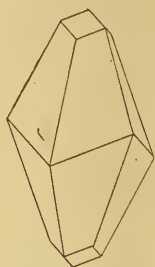


Fig. 196

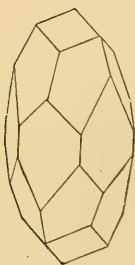


Fig. 197

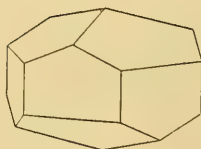
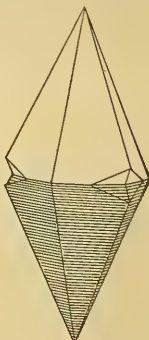
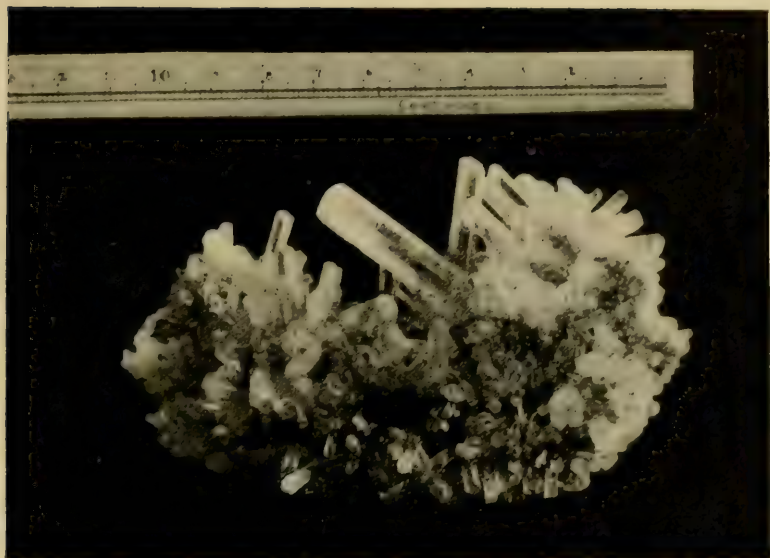
Fig. 198
Calcite

Fig. 199

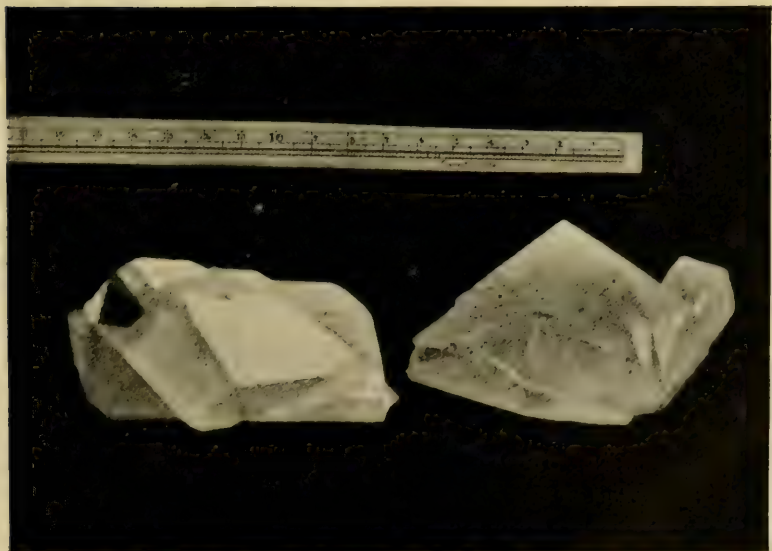
hedral cleavage, fibrous (satin spar), coarse and fine granular (crystalline limestone and marble), pulverulent (chalk), stalactitic, etc.

The luster of calcite ranges from vitreous in the crystallized varieties to dull in the limestones and chalk. It is normally colorless or white but often red, green, blue, violet, yellow, brown or black from impurities.

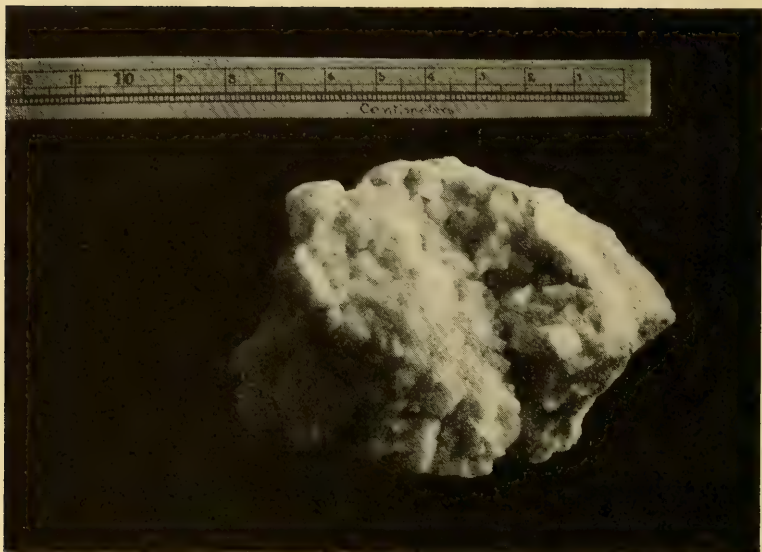
Calcite is readily distinguished by its characteristic rhombic cleavage in three directions as well as by the fact that it is easily scratched by a knife (H. 3) and that a drop of dilute hydrochloric acid will cause it to effervesce violently.



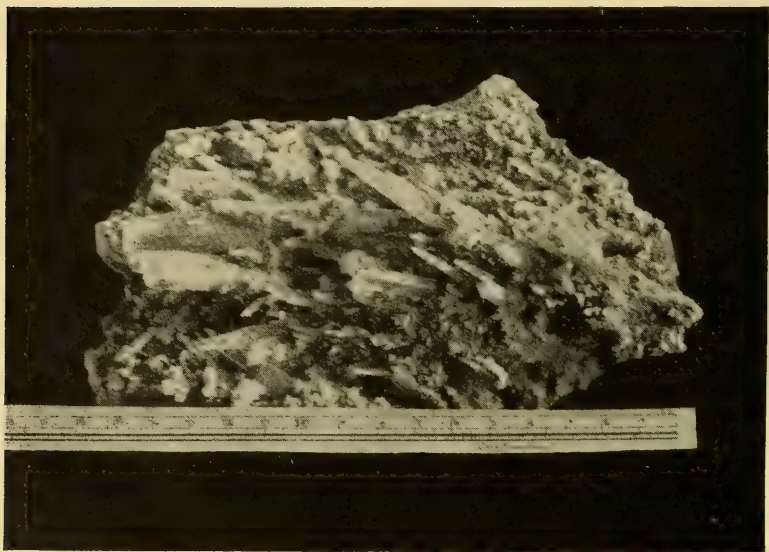
1 Calcite, Egremont, England



2 Calcite, Rossie N. Y.



1 Dolomite, Lockport N. Y.



2 Aragonite, Banat, Hungary

Calcite is probably the most widely distributed mineral. Great beds of limestone are found among the rocks of nearly every geologic horizon. Calcite also occurs as a vein mineral, in the form of stalactites and stalagmites in caves, and as a frequently associated mineral with metallic ores.

As limestone and marble, calcite is quarried to a considerable extent in Vermont, Georgia, Tennessee, Alabama, California, New York,¹ Pennsylvania and Massachusetts. Calcite in the form of limestone and marble is extensively used as a building stone; it is also burnt for quick lime, Portland and other cements and is of value as a flux for certain silicious ores. Certain varieties are used for lithographic stone, and the colorless, transparent variety is employed in optical apparatus for polarizing light.

Dolomite (pearl spar) $(\text{CaMg})\text{CO}_3$

Dolomite is the carbonate of calcium and magnesium containing 47.9% carbon dioxide, 30.4% lime and 21.7% magnesia.

In crystallization dolomite closely resembles the rhombohedral forms of calcite. It may, however, be readily distinguished from the latter by the marked curvature of the rhombohedral faces (pl. 26₁). Massive coarse or fine granular varieties are distinguished with difficulty from the corresponding forms of calcite.

The luster of dolomite is vitreous to pearly; the color is commonly white, pink or gray and less frequently rose-red, green, brown or black.

Dolomite in the form of dolomitic limestone constitutes extensive strata in many geologic formations and forms a series from pure limestone to pure dolomite. Compact and crystalline varieties frequently occur with serpentine and other magnesium minerals.

In New York dolomite is found at Lockport and Niagara Falls, Niagara co.; at Brewster, Putnam co.; Union Springs, Cayuga co., and in many other localities.¹

It is used for much the same purposes as calcite.

¹N. Y. state mus. Bul. 15. 1896.

Magnesite MgCO_3

Magnesite, the carbonate of magnesium, contains 52.4% carbon dioxid and 47.6% magnesia.

Rhombohedral crystals of magnesite are rare. It occurs commonly in granular, cleavable or compact earthy masses and as veins in serpentine. The luster is dull, sometimes vitreous or silky, and the color white, yellowish or grayish white and sometimes brown.

Magnesite is commonly associated with serpentine, talc, brucite and other magnesium minerals. Much of the marble known as verd antique is composed of serpentine veined with magnesite. It is found in Quebec, Pennsylvania, Maryland and in several places in California and Massachusetts. It has been found in the serpentine rocks of Westchester county, N. Y.

Magnesite is used as a refractory material for the lining of converters, etc.; also in the manufacture of epsom salts and carbon dioxid for soda water.

Siderite (spathic iron ore) FeCO_3

Siderite is the iron protocarbonate and contains 37.9% carbon dioxid and 62.1% iron protoxid (a composition equivalent to 48.2% iron). Manganese, magnesium or calcium may also be present in small quantities.

Siderite is rhombohedral in crystallization, the crystals being commonly rhombohedral in habit with curved faces resembling those of dolomite. It is characterized in massive varieties by the oblique rhombohedral cleavage common to this group of carbonates. In color siderite is mostly grayish yellow or brown, ranging from pale buff shades to dark brown or black. The luster is vitreous to pearly and the mineral in general resembles dolomite but is somewhat heavier and in most instances is distinguished by its brown color.

Massive siderite is often formed by the action of decaying vegetable matter on limonite. It occurs in gneiss, mica and clay slate and as clay iron stone in coal formations. It is found abundantly in Cornwall and other English localities; also in the coal formations of Pennsylvania, Ohio, Virginia and Tennessee, at Hudson and Burden, Columbia co. and at Antwerp, Jefferson co. N. Y.¹ Siderite supplies a little over 1% of American iron ore.

¹N. Y. state mus. Bul. 7. 1889.

Rhodochrosite MnCO_3

Rhodochrosite is a manganese carbonate containing 38.3% carbon dioxid and 61.7% manganese protoxid.

It occurs occasionally in rhombohedral crystals similar in shape to those of dolomite but more frequently in vitreous or pearly masses of pink to brown color with a marked rhombohedral cleavage; less frequently in globular and botryoidal forms with columnar structure or incrusting; granular or compact masses are common.

Rhodochrosite is often found associated with gold and silver ores notably at Butte Mont., in Nevada, Colorado and elsewhere. As yet it has no commercial value.

Smithsonite (dry bone ore) ZnCO_3

Smithsonite is a carbonate of zinc containing 35.2% carbon dioxid and 64.8% zinc protoxid. Small amounts of copper, cadmium, etc. frequently produce marked differences in the color.

Distinct crystals of smithsonite of rhombohedral form are of quite rare occurrence. It is commonly found in reniform, botryoidal or stalactitic masses, often with a drusy surface. It occurs also in spongy, granular and earthy forms. The luster is vitreous to dull and the color normally white or light in shade but often highly colored by impurities. The common variety of smithsonite resembles calcined bones, as indicated by the name given to it by miners.

Smithsonite is essentially a secondary product formed from other zinc ores by the action of carbonated waters. It is found in veins and beds associated with other ores of zinc as well as those of lead, copper and iron. It is found abundantly in this country in the zinc regions of Missouri, Virginia and Wisconsin.

As an ore of zinc smithsonite is highly valued on account of the ease with which it is reduced. The deposits are now nearly exhausted.

Aragonite CaCO_3

Aragonite, which is a calcium carbonate, has the same composition as calcite but differs from the latter in crystallization.

The crystals of aragonite are orthorhombic, sometimes pris-

matic in habit (fig. 200) with acute terminations (domes and pyramids) which merge into radiating needlelike forms (pl. 26₂). A twinning, which is characteristic of this group of carbonates, produces prismatic forms which somewhat resemble hexagonal prisms (fig. 201, pl. 27₁). Stalactitic incrusting, columnar and corallike forms (pl. 8₁) also occur. The prevailing color is white,

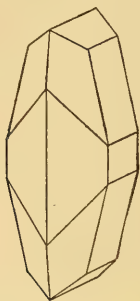


Fig. 200

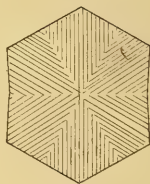


Fig. 201

Aragonite

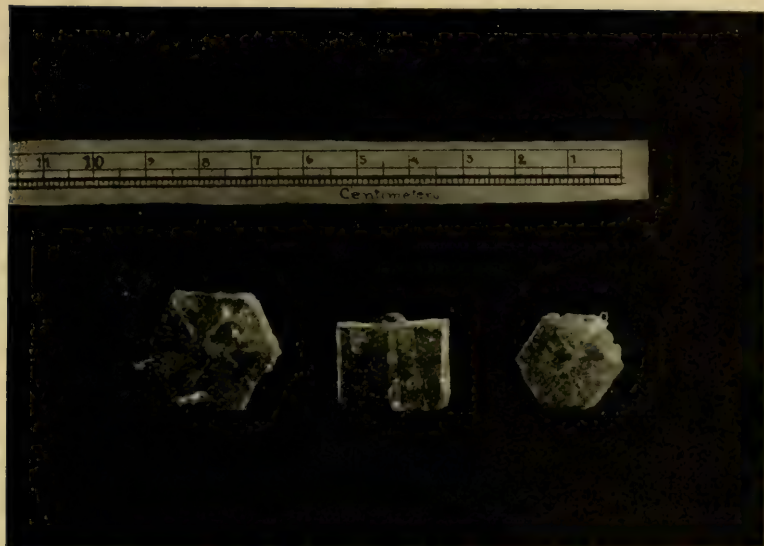
which shades to violet, yellow and pale green in some varieties; the luster is vitreous.

Crystallized varieties may be distinguished from calcite by the difference in form but massive specimens can only be determined by cleavage and optical tests. Aragonite is formed in much the same way as calcite, but is of far less common occurrence. It is often found associated with gypsum and serpentine and with iron ore as flos ferri (pl. 8₁). In the United States aragonite is found in several localities in California, in Connecticut, Illinois, Missouri, New Mexico and Pennsylvania and in Niagara, Orange and Madison counties, N. Y.

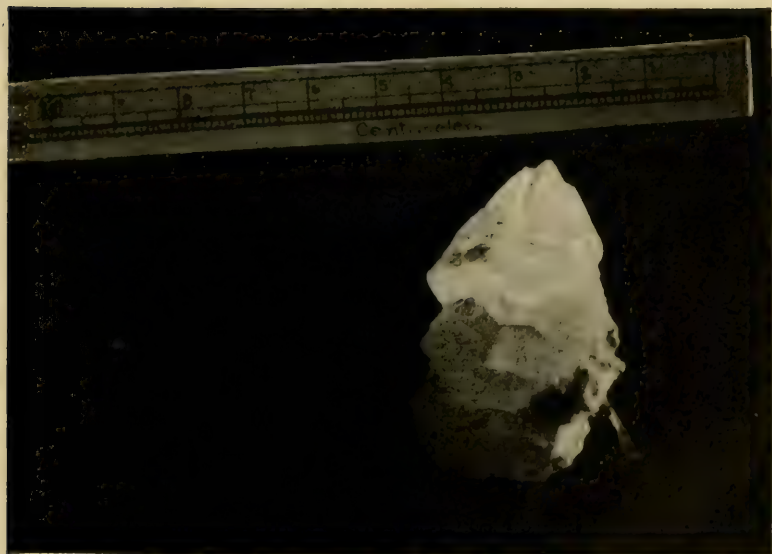
Witherite BaCO_3

Witherite is a barium carbonate containing 22.3% carbon dioxid and 77.7% baryta.

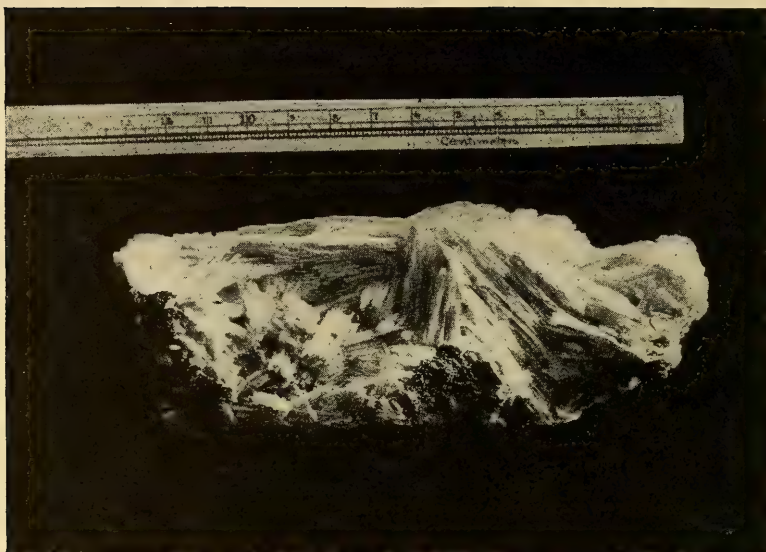
Though witherite is orthorhombic in crystallization single crystals are practically unknown; twinned forms resembling a series of hexagonal pyramids superposed are characteristic (pl. 27₂). It also occurs massive in columnar or granular structure. The luster is vitreous and the color white, gray or yellowish.



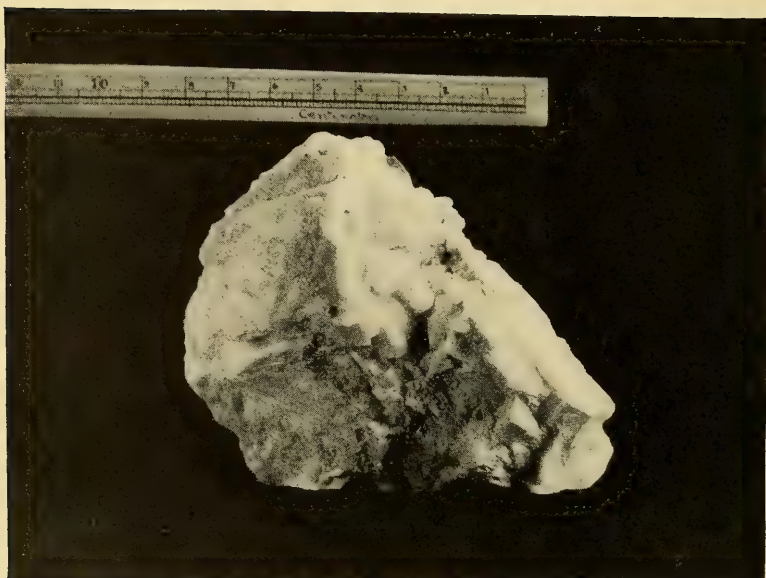
1 Aragonite, Bastenes, France



2 Witherite, Fallowfield, England



1 Cerussite, Arizona



2 Albite, Branchville Ct.

Witherite is mined at Fallowfield Eng. Small deposits of the mineral occur near Lexington Ky. and at Thunder bay, Lake Superior.

It is used as an adulterant of white lead and in the refining of beet sugar molasses.

Strontianite SrCO_3

Strontianite, the carbonate of strontium, contains 29.9% carbon dioxid and 70.1% strontia.

Distinct orthorhombic crystals are quite rare. Radiated, spear-shaped or acicular crystalline aggregates are common; also columnar, fibrous and granular masses. The luster of strontianite is vitreous and the color is white, pinkish or greenish.

Strontianite is found in New York at or near Schoharie, Schoharie co., Clinton, Oneida co. and in several localities in Jefferson county.

It is an important source of strontium compounds used in the manufacture of fireworks.

Cerussite (white lead ore) PbCO_3

Cerussite, the carbonate of lead, contains 16.5% carbon dioxid and 83.5% lead oxid. It sometimes carries a little silver.

The crystals of cerussite are orthorhombic, often of tabular



Fig. 202

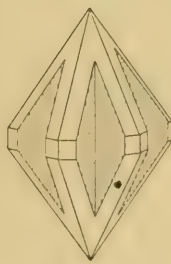


Fig. 203

Cerussite

habit, flattened parallel to the a and c axes as in fig. 202; the repeated twinning of this type yields six rayed forms as shown in fig. 203. Crystals of prismatic and pyramidal habit are also frequent. Clusters of interlaced fibrous crystals pass into silky aggregates and masses (pl. 28₁). Granular, compact or earthy

masses are common. Distinct individual crystals are commonly transparent with an adamantine luster and are colorless or white. Massive varieties are translucent to opaque and have a silky luster which in the earthy forms is nearly dull. The color is white, gray or grayish black.

Cerussite occurs with other lead minerals and results from the alteration of galena by the action of water charged with carbon dioxid. It is found in many parts of England and in central Europe; also in Pennsylvania, Virginia, North Carolina and in Wisconsin and other lead regions of the northwestern states and in Colorado and Arizona.

It is mined for lead and silver and is used in a direct process for the production of white lead.

Malachite (green carbonate of copper) $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$

Malachite is a basic carbonate of copper and contains 19.9% carbon dioxid, 71.9% copper oxid and 8.2% water.

Distinct monoclinic crystals are rare. The mineral commonly occurs in bright green masses and crusts of botryoidal surface and radiating, silky fibrous structure, showing a banding of light and dark green. It is also found in stalactitic forms and earthy masses. The luster is adamantine, silky to dull, and the color bright to dark green.

Malachite is formed by the action of water charged with carbon dioxid on other copper minerals. Large deposits are found at Bisbee Ariz. and adjacent regions. It is also found to a considerable extent in Siberia, Chile and Australia and is of frequent occurrence in all deposits of copper ore.

It is a source of copper and is frequently polished for ornamental objects.

Azurite (blue copper ore) $2\text{CuCO}_3 \cdot \text{Cu(OH)}_2$

Azurite is a basic copper carbonate differing slightly from malachite in composition. It contains 25.6% carbon dioxid, 69.2% copper oxid and 5.2% water.

Azurite occurs in monoclinic crystals of varied habit and often highly modified. Massive forms sometimes show columnar structure. As an incrustation it often has a velvety luster. It has a vitreous luster and is distinguished by its characteristic blue color.

It is formed in the same way as malachite and occurs associated with it at the localities named under the latter mineral.

Azurite is an ore of copper.

SILICATES

The members of this division are mainly important as rock-forming minerals. They are oxygen salts in which silicon is present as the acid element and are classed according as they are salts of disilicic acid ($\text{H}_2\text{Si}_2\text{O}_5$), polysilicic acid ($\text{H}_4\text{Si}_3\text{O}_9$), metasilicic acid (H_2SiO_3) or orthosilicic acid (H_4SiO_4) into disilicates, polysilicates, metasilicates, orthosilicates.

Subsilicates represent a group of basic silicates having a lower oxygen ratio than the foregoing.

Disilicates, polysilicates

Feldspar group

For many reasons the feldspars are considered the most important group of minerals in the large division of the silicates. They form an essential constituent in a number of rocks such as granite, syenite, gneiss, etc. which are of primary importance as building materials and are largely quarried in all parts of the world. As a group of minerals the feldspars present several general characteristics which unite them in close relation to each other.

1 Crystallizing in the monoclinic and triclinic systems, the feldspars agree closely in crystal habit, prism angle and methods of twinning.

2 They are characterized by two easy cleavages inclined to one another at an angle which is close to 90° , the cleavage surfaces being smooth and of high polish.

3 In hardness they vary between the comparatively close limits of 6 and 6.5.

4 They range in color from clear and colorless through white, pale shades of yellow, pink or green, to less common dark gray tints.

5 The feldspars are silicates of aluminium and some other base, commonly potassium, sodium or calcium, less frequently barium.

Orthoclase (potash feldspar) KAlSi_3O_8

Orthoclase is a silicate of aluminium and potassium. Part of the potassium is often replaced by sodium giving rise to a variety known as soda-orthoclase.

The crystals of orthoclase are monoclinic, a type of frequent occurrence being that shown in fig. 204. Types of prismatic

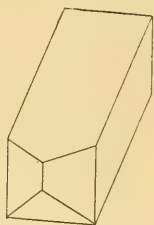


Fig. 204



Fig. 205

Orthoclase

habit, often orthorhombic in aspect from the equal development of the basal pinacoid and positive hemiorthodome (fig. 205), are often found in the transparent variety called adularia.

Twin crystals occur quite frequently and are ordinarily of three types, the Carlsbad, the Baveno and the Manebach type.¹ The cleavage of orthoclase takes place in two directions parallel to the basal and clinopinacoid and at an angle which is close to 90° . Cleavable masses are quite common. Also compact non-cleavable masses resembling flint.

The luster of orthoclase is vitreous or pearly and the color is commonly flesh-red, yellowish, white or colorless; more rarely gray or green.

Orthoclase abounds in igneous rocks and constitutes an important element in granite, gneiss and syenite and in the form of sanidine is common in the volcanic rocks rhyolite, trachyte and phonolite. It is quarried in Maine, Connecticut, Massachusetts and Pennsylvania and at Bedford and Fort Ann N. Y.

Orthoclase is used in the manufacture of porcelain and china, as a constituent of the body of the ware and also to produce the glaze.

¹These forms of twinning are illustrated by specimens and models in the collection of the New York state museum.

Microcline KAlSi_3O_8

Microcline is a triclinic feldspar having the same composition as orthoclase and was formerly grouped under that species. The crystals are so close to those of orthoclase in angle and habit that the unassisted eye is unable to distinguish between the two species. Under the polarizing microscope a characteristic gridiron structure is observable in a thin section of microcline. A characteristic variety called Amazon stone has a beautiful green color. In other respects the characteristics are essentially the same as for orthoclase.

Plagioclase feldspars

The triclinic group of minerals known as the plagioclase feldspars constitute a practically continuous series from pure soda alumina silicate in albite ($\text{NaAlSi}_3\text{O}_8$) to pure lime alumina silicate, in anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$). The intermediate species now to be discussed are mixtures of these two molecules and of necessity grade into one another, so that in many cases no marked division line can be drawn. If the albite molecule, $\text{NaAlSi}_3\text{O}_8$, be represented by Ab, and the anorthite molecule, $\text{CaAl}_2\text{Si}_2\text{O}_8$, be represented by An, the albite-anorthite series or, as they are usually called, the plagioclase feldspars, may be represented in composition as follows:

Albite	Ab	—Ab ₆	An ₁
Oligoclase	Ab ₆	An ₁ —Ab ₃	An ₁
Andesin	Ab ₃	An ₁ —Ab ₁	An ₁
Labradorite	Ab ₁	An ₁ —Ab ₁	An ₃
Bytownite (rare)	Ab ₁	An ₃ —Ab ₁	An ₆
Anorthite	Ab ₁	An ₆ —An	

The plagioclase feldspars are characterized in general by a repeated twinning parallel to the brachypinacoid which results in a series of striations on the basal cleavage surface. They form an important constituent of the igneous rocks, dacite, andesite, diorite and diabase.

Albite (soda feldspar)

Albite is a silicate of aluminium and sodium.

It occurs in triclinic crystals (fig. 206) often tabular parallel to the brachypinacoid and usually twinned parallel to the

same plane (albite law) or with the macro axis as the twinning axis (pericline law). It is common in pure white granular masses or in aggregations of straight or curved laminae. The luster is vitreous or pearly and the prevailing color white or less commonly bluish, gray, red or green of light tints; an opalescence or play of color is not uncommon on the cleavage surface.

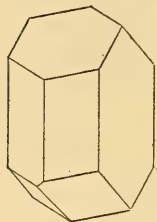


Fig. 206
Albite

Albite is frequently found in cavities and seams in acidic rocks and is frequently a matrix for such minerals as tourmalin, beryl, chrysoberyl, topaz etc. Interesting crystals of albite are found at Moriah, Essex co. N. Y.

Oligoclase (soda lime feldspar)

Oligoclase is a silicate of aluminium, sodium and calcium.

It does not often occur crystallized. Cleavable masses are characterized by the fine striations, common to the plagioclases, but particularly well developed in this species. The luster is vitreous to pearly and the color whitish with faint tints of gray, green, red or yellow.

It occurs with orthoclase and albite in granitoid rocks and in rocks of volcanic origin. Interesting crystals are found in St Lawrence county, N. Y.

Labradorite (lime soda feldspar)

Labradorite is a silicate of aluminium, sodium and calcium. It is rarely found in small triclinic crystals but is commonly met with in dark gray cleavable masses which often display a remarkable change of color as the light is reflected from a cleavage surface. The luster is vitreous to pearly and the color in general darker than that of the other plagioclases.

Labradorite is usually associated with pyroxene and amphibole in many basic rocks. It is the chief feldspar found in the Adirondack region of New York.

Anorthite (lime feldspar)

Anorthite is a silicate of aluminium and calcium. The triclinic crystals of anorthite are usually prismatic in habit, twinned, as with albite, and colorless, white or reddish yellow.

The cleavable masses are pink or gray. Granular masses of a white or reddish color are common.

Anorthite occurs in many volcanic rocks.

Metasilicates

Leucite $\text{KAl}(\text{SiO}_3)_2$

Leucite is a silicate of potassium and aluminium. It crystallizes in trapezohedrons (fig. 207) and is often found in irregular grains disseminated through lava and volcanic rock. The luster is vitreous and the color light gray or white.

Pyroxene group

The following species though falling in the orthorhombic, monoclinic and triclinic systems, exhibit a marked similarity in crystal habit and in the angle of the fundamental prism, which varies but slightly from 87° . This relation is emphasized by the fact that a more or less pronounced cleavage takes place parallel to this fundamental prism in all species referred to this group.

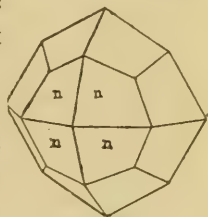


Fig. 207
Leucite

Enstatite (bronzite) $(\text{MgFe})\text{SiO}_3$

Enstatite is essentially a silicate of magnesium but often contains some iron replacing the magnesium. The iron-bearing variety is known as bronzite and grades into hypersthene with increased percentage of iron.

Enstatite rarely occurs in orthorhombic crystals of columnar habit. It is usually found in lamellar or fibrous masses, brown, gray or green in color and in the variety bronzite with a sub-metallic or bronzelike luster.

It is frequently found in basaltic and granular eruptive rocks and is quite common in stony meteorites. It occurs at Tilly Foster, Putnam co. and at Edwards, St Lawrence co. N. Y.

Hypersthene $(\text{MgFe})\text{SiO}_3$

Hypersthene is a silicate of magnesium and iron. With a decreasing proportion of iron hypersthene grades into enstatite. Orthorhombic crystals are rare. The mineral is usually found in dark green to black foliated masses, frequently showing a metalloid luster somewhat similar to that of bronzite. Hypers-

there is found in norites and other granular eruptive rocks, a series of which may be found in the vicinity of Peekskill, Westchester co. N. Y.

Pyroxene (augite)

Pyroxene is essentially a normal metasilicate of calcium and magnesium, also containing iron, manganese or zinc and sometimes small percentages of potassium and sodium. The many varieties are usually classified as nonaluminous and aluminous.

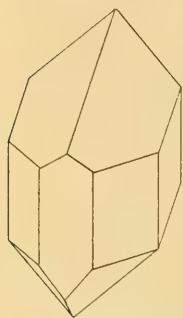


Fig. 208

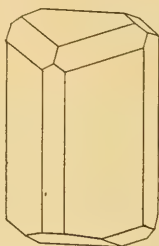


Fig. 209
Pyroxene

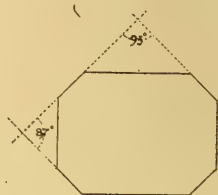


Fig. 210

Pyroxene occurs in monoclinic crystals of prismatic habit with well developed terminations (fig. 208, 209); these crystals have a nearly square or octagonal cross section composed of the faces of the unit prism which has an angle of 93° (nearly 90°) and the faces of the ortho and clino pinacoid (fig. 210). A strongly marked parting parallel to the basal pinacoid is very characteristic, and is well shown in the specimen reproduced in pl. 29₁. The crystals are often thick and short. Massive forms are granular, foliated or columnar in structure but rarely fibrous. The luster is vitreous, resinous to dull and the color usually some shade of green, but also white, brown, or black.

VARIETIES

Diopsid or malacolite $\text{CaMg}(\text{SiO}_3)_2$. Usually white or pale green in color.

Hedenbergite $(\text{CaFe})(\text{SiO}_3)_2$. Color grayish green to black.

Augite. An aluminous pyroxene chiefly $\text{CaMg}(\text{SiO}_3)_2$ but containing aluminium and iron. Color dark green, brownish green to black.



1 Pyroxene, East Russell N. Y.



2 Wollastonite, near Gouverneur N. Y.

Diallage. A foliated variety, green or brown in color.

Pyroxene is an essential constituent of many basic eruptive rocks notably the diabases and gabbros. It occurs associated with amphibole, wernerite and the feldspars. In New York pyroxene occurs in handsome specimens in Orange, Westchester, Essex and Lewis counties and specially in St Lawrence county.

Spodumene $\text{LiAl}(\text{SiO}_3)_2$

Spodumene is a silicate of lithium and aluminium.

It occurs in monoclinic crystals sometimes of considerable size which are characterized by a lamellar structure parallel to the orthopinacoid causing them to split into broad smooth plates. In the variety hiddenite the crystals are small, transparent and of a yellow-green or emerald-green color. It is also found in cleavable masses. The luster is vitreous and sometimes pearly on the cleavage surfaces, and the color white or various shades of green, pink and purple.

Spodumene occurs in granite rocks and is readily altered. Immense crystals are found at Branchville Ct. The variety hiddenite occurs at Stony Point N. C.

The emerald-green hiddenite is used as a gem.

Jadeite (jade) $\text{NaAl}(\text{SiO}_3)_2$

This is a tough translucent mineral of closely compact structure and of a general green color. It is chiefly notable as the material from which many of the prehistoric implements were made and is still used in the East, specially in China, for ornaments and utensils.

Wollastonite (tabular spar) CaSiO_3

Wollastonite is a silicate of calcium, sometimes occurring in tabular monoclinic crystals, but usually in cleavable to fibrous white or gray masses. When fibrous the fibers lie in parallel position or are arranged in reticulated bundles of parallel fibers (pl. 29₂). The luster is vitreous to silky and the color white or faint tints of gray, yellow, red or brown.

Wollastonite is found in granular limestone and as a contact mineral.

Pectolite $\text{HNaCa}_2(\text{SiO}_3)_3$

Pectolite is a silicate of sodium and calcium, and contains water.

It usually occurs in radiated aggregates of needlelike crystals which are rarely terminated (pl. 7₁). Monoclinic crystals are rare. The luster is vitreous to silky and the color white or gray.

Pectolite is found associated with the zeolites and prehnite in cavities and seams of basic eruptive rocks.

Rhodonite MnSiO_3

Rhodonite is a silicate of manganese with part of the manganese replaced by iron, calcium or zinc.

The crystals of rhodonite are triclinic, tabular parallel to the basal pinacoid, or in forms resembling pyroxene in habit but with rounded edges and angles. It also occurs in cleavable to compact masses and in embedded grains. The luster is vitreous and the color commonly brownish red, flesh-red or pink, less frequently greenish or yellowish.

Rhodonite occurs in the United States in Maine and Massachusetts and abundantly in the vicinity of Franklin N. J.

Amphibole group

This group of minerals is closely allied to the pyroxenes, forming as it does a series whose members are chemically analogous to the corresponding members of a parallel series in the pyroxene group. The two groups are also closely related crystallographically; thus a comparison of the axial ratios of pyroxene and amphibole brings out the fact that if the *a* and *c* unit intercepts for amphibole be multiplied by 2 the result will approximate very closely the actual values of the corresponding intercepts for pyroxene:

PYROXENE			AMPHIBOLE			AMPHIBOLE		
a:	b:	c	a:	b:	c	2a:	b:	2c
1.092:	1:	0.589	0.551:	1:	0.294	1.102:	1:	0.588

Amphibole (hornblende)

Amphibole is essentially a metasilicate of calcium and magnesium usually containing iron and manganese and also sodium

and potassium to some extent. As in the case of the pyroxenes the varieties are divided into nonaluminous and aluminous.

Amphibole occurs in monoclinic crystals of prismatic habit, usually with an acute rhombic section and striated vertically; a typical section is shown in fig. 211. Some of the common types

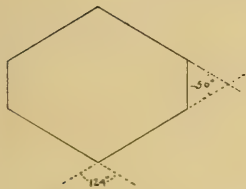


Fig. 211

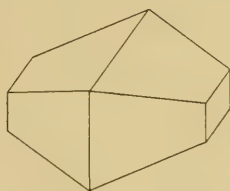
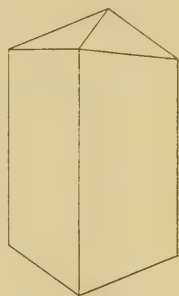
Fig. 212
Amphibole

Fig. 213

are given in fig. 212, 213. Columnar and fibrous masses are common, often radiated; also coarse or fine granular masses. The luster is vitreous to pearly and often silky. The color varies with different varieties but is mainly white, shades of green, brown or black.

VARIETIES

Tremolite $\text{CaMg}_3(\text{SiO}_3)_4$. White or dark gray in color, sometimes transparent and colorless. Luster silky.

Actinolite $\text{Ca}(\text{MgFe})_3\text{SiO}_3)_4$. Bright green to grayish green in color.

Nephrite (jade). A compact tough variety similar to the jadeite described under pyroxene.

Asbestos. A fine fibrous material white, gray, or greenish in color, easily separated into threadlike fibers.

Hornblende. An aluminous variety. Green, grayish green or black in color.

Amphibole occurs in crystalline limestone and in granitoid and schistose rocks. It is an important constituent of many granites, syenites and diorites. Good specimens have been obtained in Orange, St Lawrence and Lewis counties, N. Y.

Amphibole asbestos, which must not be confounded with the fibrous serpentine passing commercially under the same name,

is mined in California, Wyoming and Oregon. Large deposits also occur in North Carolina, Georgia, Pennsylvania and other states but these deposits are not at present worked with profit.

Asbestos is extensively used for incombustible appliances and fabrics.

Crocidolite (blue asbestos)

This is a blue to green fibrous amphibole resembling asbestos. An altered form from South Africa has the interstices between the fibers filled with silica and under the name of "tiger's eye" is sometimes cut for a cheap gem.

Beryl (emerald) $\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$

Beryl is a silicate of beryllium and aluminium. It occurs in hexagonal crystals of prismatic habit which are often striated

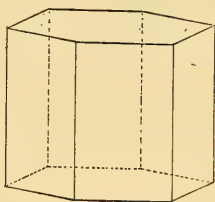


Fig. 214



Fig. 215

Beryl

vertically and are seldom terminated (fig. 214, 215). It is also found in columnar or granular masses. The luster is vitreous and the color emerald-green, pale green, light blue, yellowish white, white to colorless.

Beryl is common as an accessory mineral in granite veins. It is also found in mica schist, clay slate, etc. Beryl occurs in Maine, Massachusetts, New Hampshire, Connecticut, North Carolina, South Dakota and other states. The finest emeralds come from United States of Colombia, Brazil, India, Siberia and Australia. A few emeralds have been found at Stony Point S. C.

Emerald and a sky-blue to greenish blue variety called aquamarine are cut as gems.

Iolite (cordierite)

Iolite is a metasilicate of magnesium, aluminium and iron of somewhat complicated formula.

It occurs in short orthorhombic prisms and glassy quartzlike masses of a prevailing blue color which is deeper in one direction and more grayish or yellowish in a direction at right angles to the first.

It occurs in gneiss or granite but rarely in volcanic rocks.

Orthosilicates

Nephelite (nephelin) $K_2Na_6Al_8Si_9O_{34}$

Nephelite is an orthosilicate of sodium, potassium and aluminium.

The crystals are hexagonal-hemimorphic, prismatic in habit, terminated with a basal pinacoid sometimes slightly modified by a low pyramid. The crystals are small, sometimes transparent, with a vitreous luster, and are colorless, white or faintly yellow. Colorless or white glassy grains are found in some eruptive rocks. A common variety, called elaeolite, occurs in indistinct crystals or masses of a peculiar greasy luster and reddish brown or greenish in color.

Nephelite occurs in the more basic igneous rocks as the product of a magma rich in soda. The crystallized variety is found associated with epidote and vesuvianite in lavas and other eruptive rocks, notably in the lavas of Vesuvius. Elaeolite occurs in granular crystalline rocks and is found in Maine, Arkansas, Texas and elsewhere.

Cancrinite

An orthosilicate of sodium, calcium and aluminium generally found in yellow to white masses associated with elaeolite and blue sodalite.

It is found in the Urals, in Norway and at Litchfield and Gardiner Me.

Sodalite $Na_4(AlCl)Al_2(SiO_4)_3$

Sodalite is a chlorosilicate of sodium and aluminium. It is found in bright blue to gray masses of a vitreous to greasy luster, in concentric nodules resembling chalcedony and rarely in isometric dodecahedral crystals.

It is formed from elaeolite and its mode of occurrence is similar to that mineral.

Haüynite $\text{Na}_2\text{Ca}(\text{NaSo}_4.\text{Al})\text{Al}_2(\text{SiO}_4)_3$

Haüynite is a sodium, calcium and aluminium orthosilicate with some sodium sulfate.

Haüynite occurs in glassy rounded isometric crystals and grains of a blue to green color in igneous rocks and lavas.

Lazurite (lapis lazuli) $\text{Na}_4(\text{NaS}_3.\text{Al})\text{Al}_2(\text{SiO}_4)_3$

Lazurite is an orthosilicate of sodium and aluminium with sodium sulfid.

It occurs in deep blue masses and rarely in isometric crystals. Lazurite was formerly used as a natural pigment, producing the deep blue color known as ultramarine; it has now been almost entirely superseded by the artificial product of that name.

Garnet $\text{R}^{\text{II}}_3\text{R}^{\text{III}}_2(\text{SiO}_4)_3$

Garnet is an orthosilicate of the general formula $\text{R}^{\text{II}}_3\text{R}^{\text{III}}_2(\text{SiO}_4)_3$ in which R^{II} may be calcium, magnesium, ferrous iron, or manganese and R^{III} aluminium, ferric iron or chromium, rarely titanium. The varying proportions of these elements give rise to numerous varieties, the principal types of which will be discussed under "Varieties."

Garnet crystallizes in the normal group of the isometric system. Fig. 216-18 show the common types of crystals. It occurs

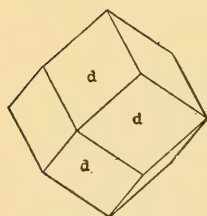


Fig. 216

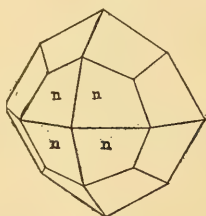


Fig. 217

Garnet

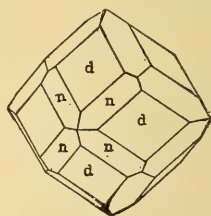
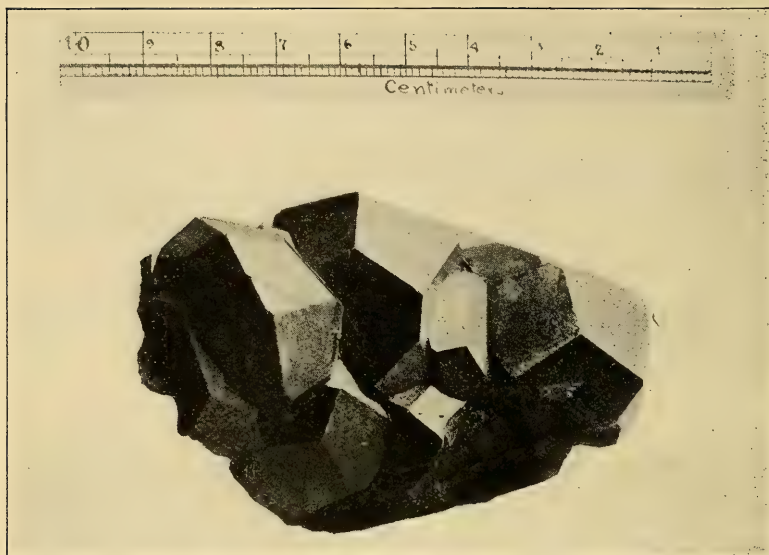


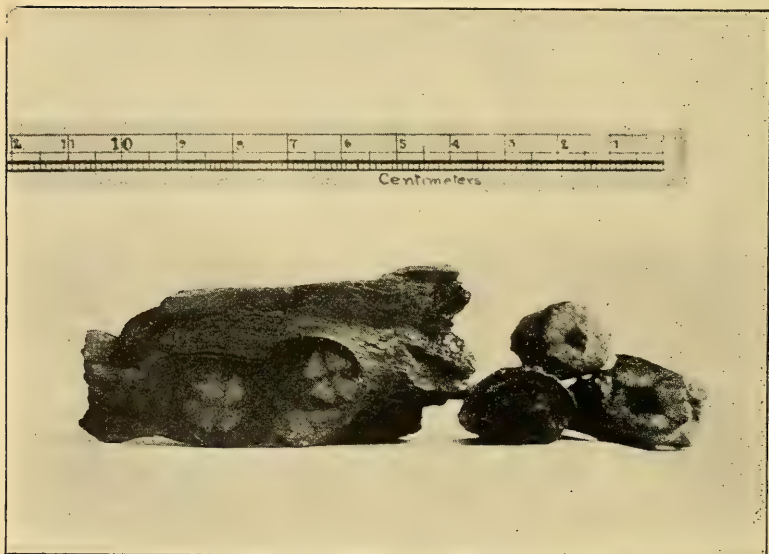
Fig. 218

in isolated, embedded crystals, in drusy incrustations and in granular, lamellar and compact masses, also as rounded grains and in sand.

The luster is vitreous to resinous and the color commonly brown, red or black but also yellow, pink, white, green and violet. In hardness garnet ranks between quartz and corundum.



1 Garnet, Russell Mass.



2 Andalusite (chiastolite), Lancaster Mass.

VARIETIES

1 Aluminium garnet. Grossularite $\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$. White, pale yellow, pale green, reddish, brown or rose-red in color, rarely emerald-green from the presence of chromium.

Pyrope $\text{Mg}_3\text{Al}_2(\text{SiO}_4)_3$. Deep red to nearly black in color. Transparent specimens are cut for gems.

Almandite $\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$. Deep red to black in color. This variety includes many of the common garnets and when transparent is cut for gems.

Spessartite $\text{Mn}_3\text{Al}_2(\text{SiO}_4)_3$. Dark hyacinth-red, violet-red to brownish red.

2 Iron garnet. Andradite $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$. Various shades of yellow, green, red, brown and black in color. This variety is quite common.

3 Chromium garnet. Uvarovite $\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3$. In minute crystals of an emerald-green color.

Garnet, particularly the variety almandite, occurs abundantly in gneiss and the crystalline schists. Grossularite is characteristic of the contact zones of intruded igneous rock in the crystalline schists. Pyrope is found in many basic igneous rocks, and spessartite in granite rocks, quartzites and whetstone schists, also in rhyolite. Uvarovite is found with chromite in serpentine and in granular limestone. Pink garnets embedded in marble are found at Mordos Mex. In New York garnet is found in Essex, Warren, Orange, Westchester and New York counties.

Garnet is extensively used as abrasive material. The Mexican marble mentioned above is polished for ornamental purposes and transparent red and green varieties are cut for gems.

Chrysolite (olivine, peridot) $(\text{Mg}, \text{Fe})_2\text{SiO}_4$

Chrysolite is an orthosilicate of magnesium and iron. It rarely occurs in orthorhombic crystals but is usually found in transparent to translucent granular masses, disseminated grains or as sand. The luster of chrysolite is vitreous and the color a yellowish green, olive-green, or bottle-green to brownish red.

Chrysolite occurs as an essential constituent of peridotite and of some gabbros. It is found in eruptive rocks such as trap, basalt, etc. and as a product of the metamorphism of certain sedimentary rocks containing magnesia and silica.

As a rock constituent chrysolite occurs in the rocks of the Cortlandt series in the vicinity of Peekskill, Westchester co. and Stony Point, Rockland co. N. Y.

Transparent varieties of olivin are cut as gems and are known to jewelers as olivins or peridots.

Willemite Zn_2SiO_4

Willemite is an orthosilicate of zinc containing 72.9% zinc oxid and 27.1% silica. A considerable part of the zinc is replaced by manganese in the variety troostite.

Willemite occurs in hexagonal crystals of the trirhombohedral class prismatic in habit. It is more commonly found in granular masses and disseminated grains. The luster is resinous and the color greenish yellow to apple-green when pure but flesh-red in the manganese bearing variety.

Willemite is chiefly found associated with franklinite and zincite in the vicinity of Franklin N.J. where it is mined for zinc.

Phenacite Be_2SiO_4

Phenacite is the orthosilicate of beryllium. It occurs in transparent hexagonal crystals, trirhombohedral, which are commonly small, lens-shaped and transparent and white or yellowish in color.

It occurs with microcline, beryl, quartz and topaz and is found in the Urals, in Mexico and at Pike's peak Col. It is sometimes cut for an imitation gem.

Diopase H_2CuSiO_4

Diopase is a basic copper orthosilicate occurring in rhombohedral crystals and crystalline aggregates of a vitreous luster and emerald-green in color; also massive.

Wernerite (scapolite)

Wernerite is an aluminium, sodium and calcium chlorosilicate of variable composition, usually containing some soda.

The crystals of wernerite are tetragonal, of the general type shown in fig. 219, and are characterized by the low pyramidal termination. They are commonly coarse and thick, often with rounded edges and angles and with a characteristic fibrous appearance on the cleavage surfaces. Wernerite also occurs in

columnar and granular masses. The luster is vitreous to dull, and the color is usually gray, dull green or white, sometimes bluish or reddish.

Wernerite occurs in metamorphic rocks and is abundant in granular limestone near the contact with granite or other igneous rocks. It is associated with pyroxene, amphibole, apatite, etc. In New York wernerite is found in Orange, Essex and Lewis counties and abundantly in Jefferson and St Lawrence counties.

Vesuvianite (idocrase)

Vesuvianite is a basic calcium-aluminium silicate of uncertain formula with some of the calcium replaced by manganese and some of the aluminium by iron. Fluorine and titanium may be present.

The crystals are tetragonal, prismatic or pyramidal in habit, the prismatic crystals often exhibiting the general type shown in fig. 220. Columnar masses occur straight, radiated or irregular, often producing characteristic striations parallel to the vertical axis. The luster is vitreous to resinous and the color commonly brown, green or some intermediate shade, rarely yellow or blue.

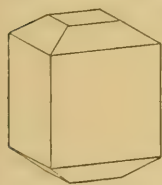


Fig. 220
Vesuvianite

Vesuvianite commonly occurs as a contact mineral from the alteration of impure limestone; also in serpentine, chlorite schist, gneiss and other metamorphic rocks; in the former case it is usually associated with garnet, phlogopite, pyroxene, wollastonite, etc. It is found in Canada, Maine, New Hampshire and New Jersey and in Orange county and other localities in New York.

Zircon (hyacinth) ZrSiO_4

Zircon is a silicate of zirconium usually containing a little iron sesquioxid.

It occurs in tetragonal crystals, prismatic in habit, of the general types shown in fig. 221-23, but sometimes pyramidal with the prism only slightly developed. Twins similar to those of cassiterite and rutile occur. Zircon is also found in irregular lumps and grains. The luster is adamantine and the color

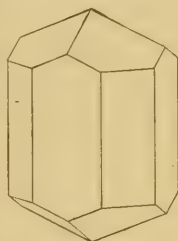


Fig. 219
Wernerite

usually brown, reddish or gray but also colorless, green or yellow. Zircon is somewhat harder than quartz.

Zircon occurs chiefly in granite, gneiss, crystalline limestone and other crystalline rocks and in alluvial deposits; often in auriferous sands; sometimes also in volcanic rocks. Interesting specimens of zircon have been found in Orange, Essex and St Lawrence counties, N. Y. It is mined in North Carolina.



Fig. 221

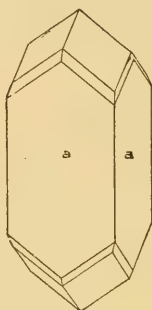
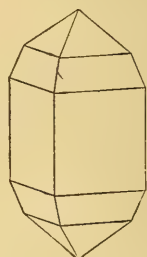
Fig. 222
Zircon

Fig. 223

Zircon is the chief source of zirconium oxid used in certain incandescent light mantles. Transparent red and brown varieties are cut as gems and are known to jewelers as hyacinth, a term also used in connection with garnet.

Topaz $\text{Al}_{12}\text{Si}_6\text{O}_{25}\text{F}_{10}$

Topaz is an aluminium fluosilicate.

The crystals are orthorhombic, prismatic in habit, frequently with complicated terminations (fig. 224, 225) and often striated

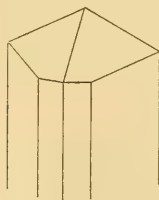


Fig. 224

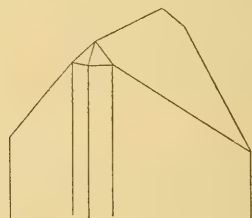


Fig. 225

Topaz

vertically on the prismatic faces. They show perfect cleavage parallel to the base, the cleavage surfaces presenting beautifully polished reflecting planes. They are usually attached and

are consequently rarely terminated at both ends. Topaz occurs also in columnar masses and rolled fragments.

The luster is vitreous and resembles that of quartz; the crystals are colorless, yellow, reddish, bluish, faintly green or pink; massive varieties are often white. The hardness exceeds that of quartz but is not as high as corundum.

Topaz occurs in veins and cavities in the highly acid igneous rocks such as granite, rhyolite, etc. and sometimes in gneiss and schists. It is often found in alluvial deposits with stream tin. It is commonly associated with fluorite, cassiterite and tourmalin.

It is found in Saxony, the Urals, Japan, Brazil, Mexico; and in Maine, Colorado and Utah.

Transparent varieties are cut for gems.

Andalusite Al_2SiO_5

Andalusite is an orthosilicate of aluminium.

It occurs in coarse orthorhombic crystals nearly square in cross section or in tough columnar or granular masses. The variety chiastolite occurs in rounded prisms which are characterized by carbonaceous inclusions symmetrically arranged with respect to the vertical axis; these show on a fracture, a cross or tessellated figure as in pl. 30₂. The luster is vitreous inclining to pearly; the color varies from white or light gray through light green or violet to rose-red or flesh-red.

Andalusite occurs in imperfectly crystalline schist, in gneiss, mica schist and other metamorphic rocks. Chiastolite is commonly a contact mineral in clay slates adjoining granite dikes. It is found in Andalusia, Spain; Brazil and in many localities in the New England states, Pennsylvania and California.

Sillimanite (fibrolite) Al_2SiO_5

An orthosilicate of aluminium with the same composition as andalusite. It occurs in long slender orthorhombic crystals, in parallel groups passing into fibrous or columnar masses, brown or gray in color and extremely tough in tenacity. Its mode of occurrence is similar to that of andalusite.

Cyanite (disthene) Al_2SiO_5

Cyanite is probably a basic metasilicate of aluminium with the formula $(\text{AlO})_2\text{SiO}_3$. Dana, however, places it for convenience in the group with sillimanite, to which mineral it bears a close relation.

Cyanite is found in long bladelike, triclinic crystals which are rarely terminated and in coarsely bladed columnar masses usually of a grayish blue color (pl. 2.). It cleaves easily parallel to the three pinacoids. The luster is vitreous to pearly and the color commonly blue along the center of the blades, shading to white on the edges; also gray, green to nearly black.

It occurs in gneiss and mica schist with garnet and staurolite and is often associated with corundum. It is found in the corundum regions of Massachusetts, Pennsylvania, North Carolina and Georgia; it has been noted in the rocks of New York island.

Cyanite is sometimes used as a gem.

Datolite $\text{Ca}(\text{BOH})\text{SiO}_4$

Datolite is a basic calcium and boron orthosilicate.

It crystallizes in monoclinic forms of varied habit but usually short prismatic (fig. 226) and often highly modified. The crystals are glassy, transparent or translucent and colorless, white or pale green. A massive compact variety has a dull luster resembling unglazed porcelain and is gray or pinkish in color.

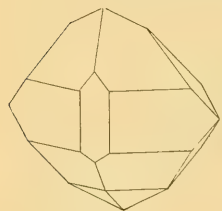


Fig. 226
Datolite

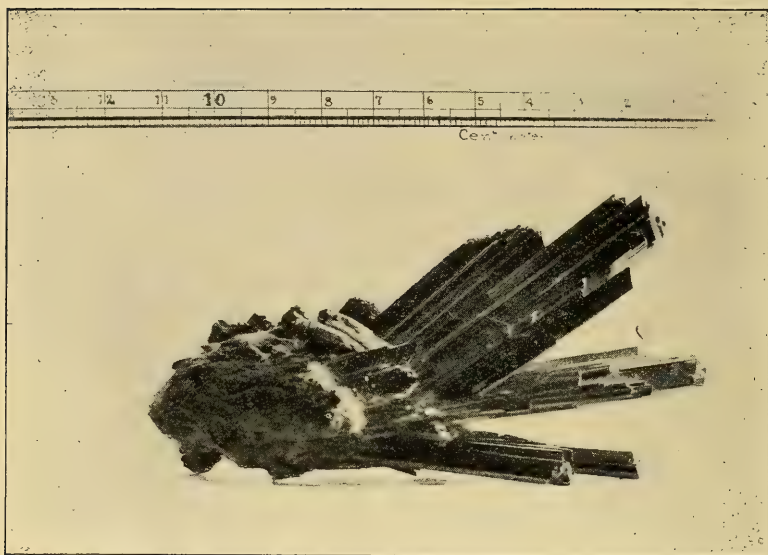
Datolite occurs as a secondary mineral in veins and cavities in basic eruptive rocks associated with calcite, prehnite and the zeolites; also in metallic veins as in the Lake Superior copper region where the massive variety is quite common. It is also found in the vicinity of Bergen Hill and Paterson N. J. and in other localities throughout New York¹ and New England.

Epidote $\text{HCa}_2(\text{Al,Fe})_3\text{Si}_3\text{O}_{13}$

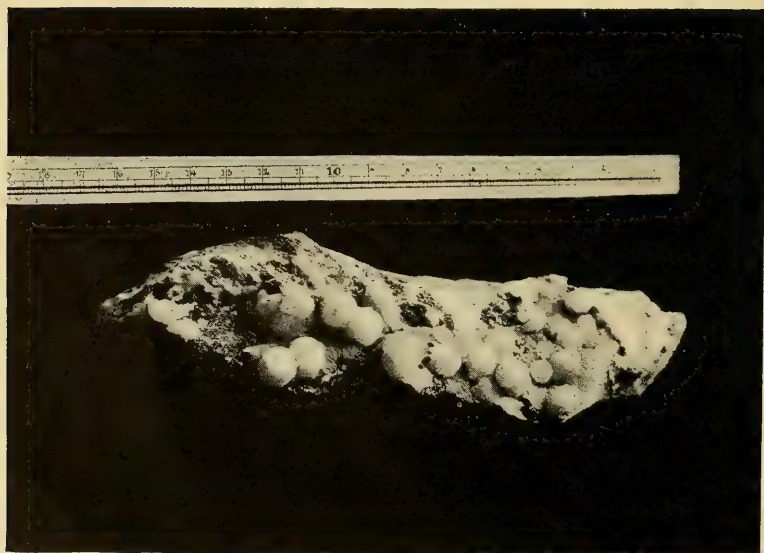
Epidote is a basic calcium, aluminium and iron silicate.

It occurs in monoclinic crystals which are commonly elongated

¹ A few rare occurrences are noted in St Lawrence county. See Dana, J. D. System of mineralogy. 1892.



1 Epidote, Sulzbach, Tyrol



2 Prehnite, West Paterson N. J.

in the direction of the orthoaxis producing forms of horizontal prismatic habit (fig. 227). These pass into acicular forms, striated in the direction of elongation, columnar, parallel or divergent, and fibrous masses (pl. 31₁). It also occurs coarse to fine granular. The luster is vitreous, the crystals sharp and with brilliantly reflecting faces; the color is commonly some shade of pistachio-green, often nearly black, also yellowish green, gray or brown.

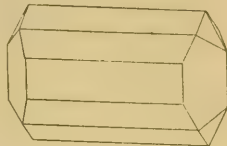


Fig. 227
Epidote

Epidote occurs in metamorphic rocks of the older formations, in gneiss, mica and hornblende schists. It is found associated with quartz, the feldspars, actinolite and minerals of the chlorite group. It is common in New England and in many of the western states. Handsome specimens have been found in Orange and Putnam counties, N. Y.

Axinite $\text{H}_2\text{Ca}_4(\text{BO})\text{Al}_3(\text{SiO}_4)_5(?)$

Axinite is an aluminium and calcium borosilicate with some of the calcium replaced by iron and manganese. It occurs in sharp triclinic crystals with acute edges (fig. 228), clove-brown, bluish or yellow in color and in lamellar and curved lamellar masses. The luster is highly vitreous.



Fig. 228
Axinite

Prehnite $\text{H}_2\text{Ca}_2\text{Al}_2(\text{SiO}_4)_3$

Prehnite is an acid calcium and aluminium orthosilicate.

It is rarely found in isolated orthorhombic crystals of tabular habit but usually occurs in aggregates of such crystals united by their basal planes and producing barrellike, sheaflike and botryoidal shapes (pl. 31₂) with crystalline surfaces. The luster is vitreous, faint pearly on the basal planes; the color is light green to oil green, yellowish green, gray to white.

Prehnite occurs as a secondary mineral in veins and cavities in basic eruptive rocks, basalt, diabase, etc. also in gneiss and granite associated with calcite, pectolite, datolite and the zeolites. It is sometimes associated with the copper of the Lake Superior region. Beautiful specimens are found in the neighborhood of Bergen Hill and Paterson N. J.

It is occasionally cut as a gem.

Subsilicates

The minerals here included are probably either metasilicates or orthosilicates, which, for lack of definite knowledge regarding their constitution, have been classed by Dana under this head.

Humite group

This group includes the species chondrodite, humite and clinohumite. They are basic fluosilicates of magnesium and are closely related chemically. They occur in crystals which are extremely complicated (chondrodite and clinohumite are monoclinic, and humite is orthorhombic). Clinohumite and chondrodite occur in compact masses and disseminated grains. A vitreous to resinous luster is common to the group and the general color is red, brownish red, brown to yellow.

The humite group occur mainly in ejected masses of limestone and are associated with chrysolite, biotite, pyroxene, magnetite, spinel, etc. The minerals of the humite group are all found at the Tilly Foster mine, Putnam co. N. Y.

Calamin H_2ZnSiO_5

Calamin is a basic zinc silicate containing 67.5% zinc oxid, 25% silica and 7.5% water.

The crystals are orthorhombic-hemimorphic, usually tabular parallel to the brachypinacoid (fig. 229) and are frequently joined in radiated groups forming a rounded notched ridge or cockscomb (pl. 32₁). Granular, stalactitic and botryoidal masses are also found. The luster is vitreous to pearly. Isolated crystals are occasionally colorless and transparent; in general the color is white, more rarely delicate shades of blue or green and yellow to brown in the massive varieties.

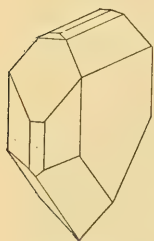


Fig. 229
Calamin

Calamin usually accompanies smithsonite in veins and cavities in stratified calcareous rocks associated with the sulfids of zinc, iron and lead. It is mined in considerable amounts in Silesia and Rhenish Germany. In the United States it occurs extensively at Granby Mo.; also at Sterling Hill N. J., Bethlehem Pa. and in Virginia, Pennsylvania, Utah and Montana.

As an ore of zinc it is valued as being comparatively free from volatile impurities.



1 Calamin, Franklin N. J.



2 Tourmalin (rubellite) on lepidolite, San Diego county, Cal.

Tourmalin (schorl)

Tourmalin is a complex silicate of boron and aluminium with appreciable amounts of either magnesium, iron or the alkali metals.

It crystallizes in the rhombohedral-hemimorphic class of the hexagonal system in prismatic crystals, sometimes short and thick as in fig. 230 or elongated with vertical striations, but



Fig. 230

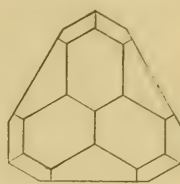


Fig. 231

Tourmalin

always presenting a somewhat triangular cross section (fig. 231). Where doubly terminated the crystals show different modifications on the two extremities. Parallel or radiated crystal aggregates are common as well as columnar and compact masses (pl. 32₂). The luster is vitreous to resinous; the color is commonly black, brown or bluish, also blue, green, pink, or red, rarely colorless or white. Some varieties are composed of an internal core of red surrounded by a layer of green, others are differently colored at the opposite extremities.

Tourmalin occurs in crystalline rocks such as granite, gneiss, mica schist, crystalline limestone, etc. The brown variety is generally found in granular limestone and dolomite; a bluish black kind is often associated with the tin ores; black tourmalins are common in quartz, granite, gneiss and mica schist; rubellite, a pink to red variety, is found in lepidolite. In New York tourmalin is found in handsome specimens in St Lawrence county; at Gouverneur and Pierrepont; also in Essex, Orange and New York counties.

Transparent varieties are sometimes cut as gems or for use in certain optical apparatus.

Staurolite $\text{HFeAl}_5\text{Si}_2\text{O}_{13}$

Staurolite is a basic iron and aluminium silicate with magnesium (and sometimes manganese) replacing part of the ferrous iron.

It occurs in orthorhombic crystals of prismatic habit which are often twinned, producing crosslike forms (pl. 33₁). The luster is resinous to vitreous and the color varies from a blackish brown to dark brown or gray.

Stauroilite is usually found in metamorphic rocks such as gneiss, mica schist and argillaceous schists as a result of regional metamorphism and is frequently associated with garnet, sillimanite, cyanite and tourmalin. It occurs throughout the mica schists of New England, in North Carolina and Georgia. A few occurrences are noted in the mica schists of New York as the result of contact metamorphism, as at Peekskill, Westchester co.¹

Hydrous silicates

The species here included contain water of crystallization, as is the case with the zeolites, or yield, on ignition, water which is present as a base; in the latter category belong the micas and talc. In a third type of silicates referred to this division the relation of the water contained to the general composition is still in doubt.

Zeolite division

Apophyllite $H_7KCa_4(SiO_3)_8+4\frac{1}{2}H_2O$

Apophyllite is a hydrous potassium and calcium silicate.

It occurs in tetragonal crystals, mostly of square cross section, sometimes flattened in the direction of the vertical axis into plates; and in rectangular forms, somewhat isometric in aspect but striated on the prismatic faces and giving pearly reflections from the basal plane (pl. 33₂); it is often found with steep pyramidal terminations (fig. 232). It is also found occasionally in lamellar masses. The luster is vitreous except on the basal pinacoid which face has a pearly luster with internal opalescence often likened to the eye of a fish; it is colorless, white, pink or greenish.



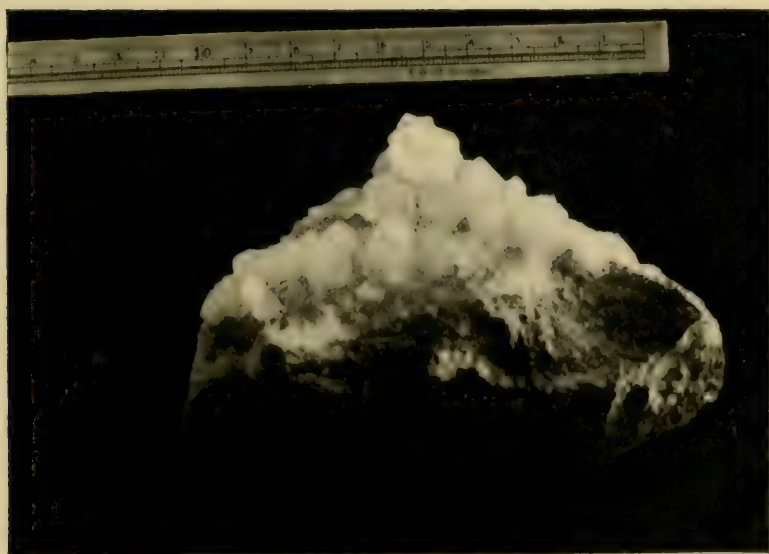
Fig. 232
Apophyllite

Apophyllite occurs as a secondary mineral in basalt and other volcanic rocks associated with the zeolites, datolite, prehnite, and calcite; also in cavities in granite and gneiss. Nova Scotia, the Lake Superior copper region and Bergen Hill N. J. afford many good specimens.

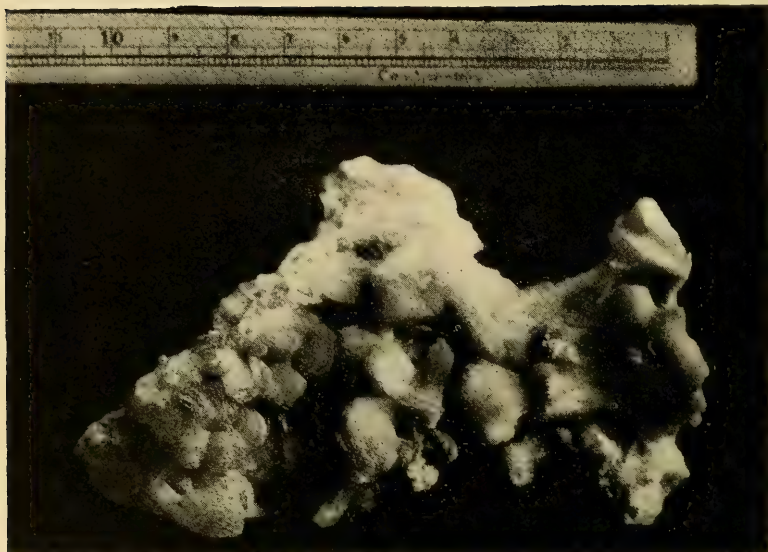
¹ Williams, G. H. Contact metamorphism near Peekskill N. Y. Am. Jour. sci. 1888. 36: 254.



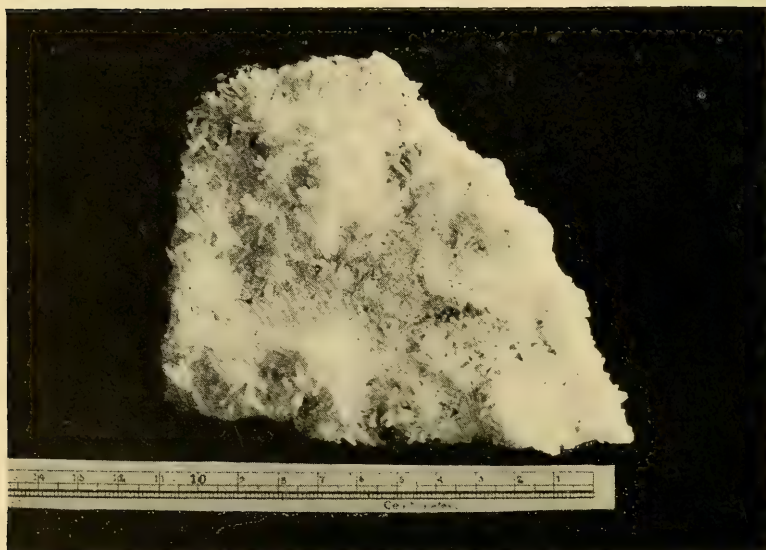
1 Staurolite, Fanning county, Ga.



2 Apophyllite, West Paterson N. J.



1 Stilbite, Partridge Island N. S.



2 Natrolite, Weehawken N. J.

Heulandite $\text{H}_2\text{CaAl}_2(\text{SiO}_3)_6+3\text{H}_2\text{O}$

Heulandite is a hydrous calcium and aluminum silicate.

It occurs in monoclinic crystals, somewhat coffinlike in shape with marked cleavage parallel to the clinopinacoid and a pearly luster on the clinopinacoid and cleavage surfaces. The crystals are sometimes joined in parallel position, giving ridgelike forms of the general coffinlike section. The luster is pearly to vitreous and the color white, red or brown.

Heulandite occurs with the other zeolites in basaltic rocks and gneiss. For localities see apophyllite.

Stilbite (desmine) $\text{H}_4(\text{Na}_2,\text{Ca})\text{Al}_2(\text{SiO}_3)_6+4\text{H}_2\text{O}$

Stilbite is a hydrous sodium, calcium and aluminium silicate.

It occurs in monoclinic crystals resembling those of heulandite but usually more tabular parallel to the clinopinacoid and with a more strongly marked tendency to form aggregates which are sheaflike (pl. 34), globular or radiated in form. The broad faces of the tabular crystals show a pearly luster, otherwise the luster is vitreous; the color is white, red, brown or yellow.

Stilbite occurs in the formations and localities common to the zeolites, for which see apophyllite.

Chabazite $(\text{Ca},\text{Na}_2)\text{Al}_2(\text{SiO}_3)_4+6\text{H}_2\text{O}$

Chabazite is a hydrous calcium, sodium and aluminium silicate.

It occurs in rhombohedral crystals with nearly square faces, which give them somewhat the aspect of cubes. These faces, however, are commonly striated parallel to the edges and are often broken by the protuberance of an angle of the twinned negative rhombohedron. The luster is vitreous and the color white or flesh-red.

Chabazite like the other zeolites is found generally in basaltic rocks. It is abundant in several localities in Nova Scotia.

Analcite $\text{NaAl}(\text{SiO}_3)_2+\text{H}_2\text{O}$

Analcite is a hydrous sodium and aluminium silicate.

It occurs in isometric crystals, usually trapezohedrons (fig. 233). A variety from the Cyclopean islands near Sicily is cubic in habit with small trapezohedral modifications. It is sometimes found in concentric groups about a single crystal as a

nucleus and more rarely in granular or compact masses with concentric structure. The luster is vitreous and the crystals are colorless or white, greenish or faintly red in color.

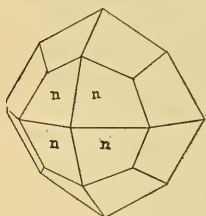


Fig. 233
Analcite

Analcite is a secondary mineral occurring with other zeolites in the basalt or gneiss at the prominent zeolite localities previously given under apophyllite.

Natrolite $\text{Na}_2\text{Al}_2\text{Si}_3\text{O}_{10} + 2\text{H}_2\text{O}$

Natrolite is a hydrous sodium and aluminium silicate.

It occurs in slender, orthorhombic prisms of nearly square cross section often terminated by a flat pyramid (fig. 234); these are commonly grouped in radiating and interlacing aggregates (pl. 34₂). It also occurs in radiating fibrous forms and granular to compact masses. The luster is vitreous; the color is white, greenish or reddish, the crystals are frequently colorless.

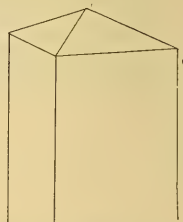


Fig. 234
Natrolite

The manner of occurrence, association and localities are the same as for the other zeolites.

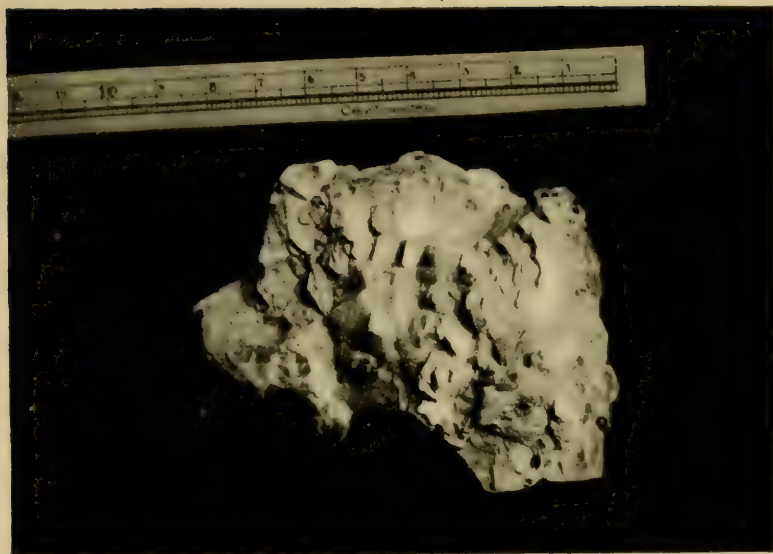
Mica division

Muscovite (common mica, isinglass) $\text{H}_2\text{KAl}_3(\text{SiO}_4)_3$

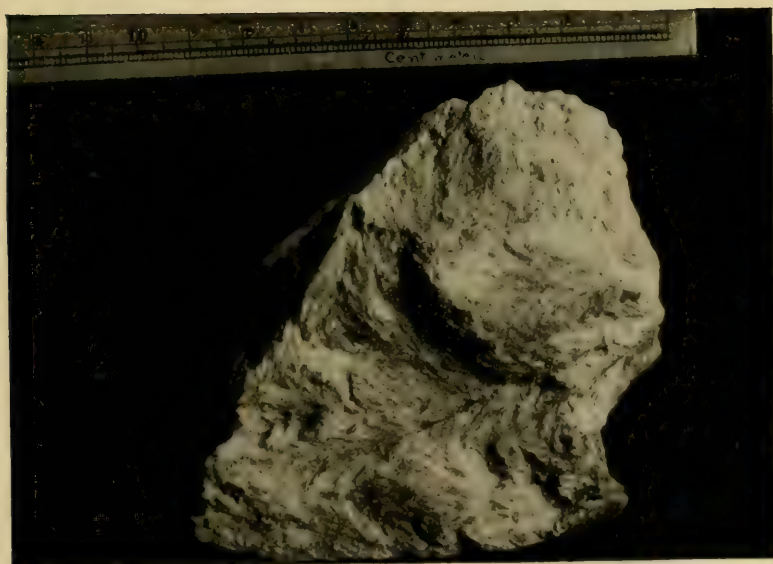
Muscovite is a hydrous potassium and aluminium orthosilicate.

The crystals of muscovite are monoclinic, prismatic and tabular in habit, with a rhombic or hexagonal section and cleave with great ease parallel to the base into extremely thin elastic plates. It also occurs in disseminated scales, often grouped in globular (pl. 35₁) or plumose (pl. 35₂) forms. The luster of muscovite is vitreous, pearly on the cleavage planes; the color is commonly gray, brown, green or yellow, sometimes violet or black.

Muscovite is the most common of the micas and is very widely distributed. It is an essential constituent of mica schist and, to a less degree, of some granite and gneiss. The best developed crystals occur in pegmatite dikes and veins. It is also found in fragmental rocks and limestones but rarely as a secondary mineral in volcanic rocks.



1 Muscovite, Stowe Me.



2 Muscovite (plumose), Minot Me.

Muscovite is mined in South Carolina and New Hampshire. Deposits of good quality also exist in Pennsylvania, Colorado, Nevada, New Mexico, South Dakota, Washington and California. Muscovite has been found in Westchester, Orange, Jefferson and St Lawrence counties, N. Y.

Muscovite, known commercially as mica and colloquially as isinglass, is much used for the doors of furnaces and stoves, also as an insulating material in dynamos and other electric appliances and for many less important purposes.

Lepidolite (lithia mica)

Lepidolite is a basic fluosilicate of potassium lithium and aluminium. It occurs in crystalline plates resembling those of muscovite but of a pinkish or violet-gray color often nearly white. More frequently it is found in massive granular aggregates of coarse or fine scales. It cleaves easily parallel to the base into elastic plates. It is distinguished from muscovite mainly by the color.

It is found in granite and gneiss particularly in pegmatite veins.

Biotite (black mica) $(\text{H,K})_2(\text{Mg,Fe}^{\text{II}})_2(\text{Al,Fe}^{\text{III}})_2(\text{SiO}_4)_2$

Biotite is a potassium, magnesium, aluminium, ferrous and ferric iron orthosilicate.

It occurs in monoclinic crystals, tabular or short prismatic in habit, similar to those of muscovite. These show the basal cleavage characteristic of the micas, separating into thin elastic plates. It is often found in disseminated scales or in massive aggregates of cleavable scales. The luster is vitreous, pearly, or, in the dark colored varieties, submetallic; the color is commonly dark green to black.

Biotite occurs as an important constituent in many igneous rocks and is common in most granites, and in many syenites and diorites; also in such eruptive rocks as rhyolite, trachyte and andesite. In small flakes biotite is present in many common rocks and soils.

Orange, Essex and St Lawrence counties, N. Y. furnish good specimens.

Phlogopite (amber mica) $(\text{H,K,MgF})_3\text{Mg}_3\text{Al}(\text{SiO}_4)_3$

Phlogopite is a potassium, magnesium and aluminium fluo-silicate.

The crystals of phlogopite are similar to those of muscovite and biotite but are often developed into rather longer prismatic forms usually tapering slightly at either end. The color is commonly yellowish brown to brownish red, frequently a metallic copper-red on the cleavage surfaces.

It is specially characteristic of crystalline limestone and is also found in serpentine. Localities are numerous throughout New York, particularly in Jefferson and St Lawrence counties, and in New Jersey.

Phlogopite is used largely as an insulating material in electric work.

Clinochlore (ripidolite) $\text{H}_8\text{Mg}_5\text{Al}_2\text{Si}_3\text{O}_{18}$

Clinochlore is a basic magnesium and aluminium silicate.

It occurs in monoclinic crystals closely approximating hexagonal forms in prism angle. The crystals cleave easily into thin, inelastic plates resembling those of the micas. It is also found in masses of coarse or fine scales and in an earthy variety. In color clinochlore is commonly some shade of green, more rarely yellowish, white or rose-red.

It is frequently found in chlorite and talcose rocks and in serpentine. Clinochlore partly altered to serpentine occurs with magnetite at Brewster, Putnam co. N. Y.

Prochlorite $\text{H}_{40}(\text{FeMg})_{23}\text{Al}_{14}\text{Si}_{13}\text{O}_{90}$

Prochlorite is a basic magnesium and aluminium silicate with some iron and a lower percentage of silica than clinochlore.

It is monoclinic, the crystals are commonly small with strongly furrowed prismatic faces and often curiously twisted into wormlike shapes. It is also found in foliated and granular masses. The color varies from grass-green to blackish green and the luster from feebly pearly to dull.

It frequently results from the decomposition of mica, amphibole, garnet, pyroxene, etc. Its association and occurrence are similar to clinochlore.

Serpentine and talc division

Serpentine $\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$

Serpentine is a hydrous magnesium silicate with some of the magnesium replaced by iron.

Serpentine occurs only in massive forms and in pseudomorphs after crystals of chrysolite, amphibole, pyroxene, enstatite, etc. It is sometimes foliated but also occurs in delicate silky fibers (pl. 3₁) and in fine granular to impalpable masses. It is characterized by a greasy feel. The color is green of various shades, yellow, brown, red, black and nearly white, often gray on exposure and frequently variegated. The luster is greasy, silky or waxy.

Serpentine is a secondary mineral resulting from the alteration of certain magnesium silicates and frequently forms large rock masses. When formed from the alteration of basic igneous rocks it is associated with spinel, garnet, chromite and sometimes ores of nickel. The variety derived from the decomposition of metamorphic rocks is commonly accompanied by dolomite, magnesite and other carbonates. A variegated rock of the latter type is polished for ornamental purposes and goes by the name of verd antique marble; this is quarried at Milford Ct. A fibrous variety known as chrysotile is mined in Quebec and is used as asbestos. Outcrops of serpentine are found in Westchester county at New Rochelle, Rye and Port Chester, and in Putnam, Orange, Richmond, Jefferson and St Lawrence counties, N. Y.

Talc (steatite, soapstone) $\text{H}_2\text{Mg}_3(\text{SiO}_3)_4$

Talc is an acid metasilicate of magnesium.

Owing to the extreme rarity of crystallized specimens its system of crystallization is still in doubt. It commonly occurs in foliated or fibrous masses (pl. 3₂), sometimes with a stellated structure, and in coarse or fine granular to compact masses. These vary in hardness (H1-1.5) but are in general very soft with a soapy feel. The color is ordinarily white, greenish or gray and the luster pearly or waxy.

VARIETIES

Foliated talc. A light green to white foliated variety which may be separated into thin, inelastic plates.

Soapstone or steatite. A coarse to fine granular talc of a gray or green color; used extensively for making sinks and as a refractory material for hearths, stove linings, etc.

French chalk. A soft compact material used by tailors for marking cloth.

Agolite. A fibrous variety of talc somewhat above the average hardness and used when mixed with wood pulp in the manufacture of paper.

Rensselaerite. A name given to the pseudomorphs of talc after pyroxene.

Talc in the form of soapstone is very common, and in some regions constitutes quite extensive beds. It is often associated with serpentine, chlorite schist and dolomite and frequently forms pseudomorphs after other minerals. An extensive deposit at Talcville, St Lawrence co. N. Y. is mined for the manufacture of paper and for a fireproof fiber which is mixed with serpentine asbestos.¹

Besides the uses above mentioned talc is used in making soap, as a dressing for skins and as a lubricant.

Sepiolite (meerschaum) $H_4Mg_2Si_3O_{10}$

Sepiolite is a silicate of magnesium containing water. It occurs in soft, compact, white, amorphous masses of an earthy texture and with a dull luster. It is rarely fibrous.

Sepiolite is found in Asia Minor, Greece, Morocco, Moravia and in Spain where it is used as a building stone. The material from Asia Minor is used for making meerschaum pipes.

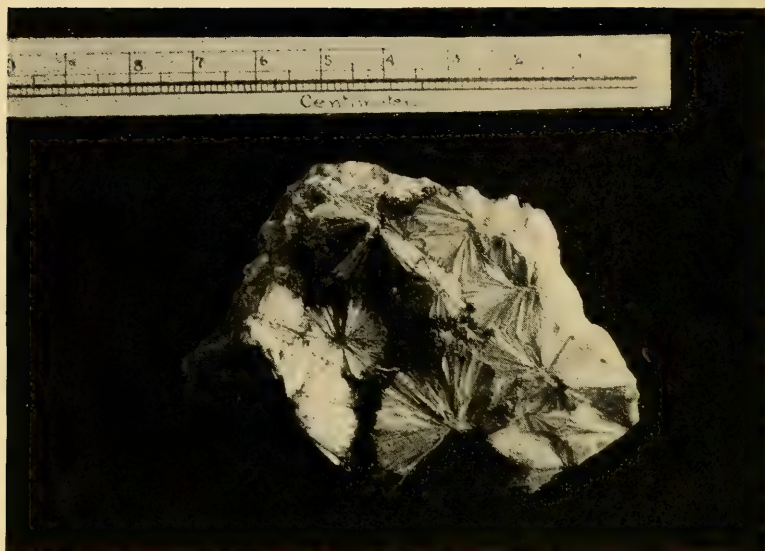
Kaolin division

Kaolinite (kaolin) $H_4Al_2Si_2O_9$

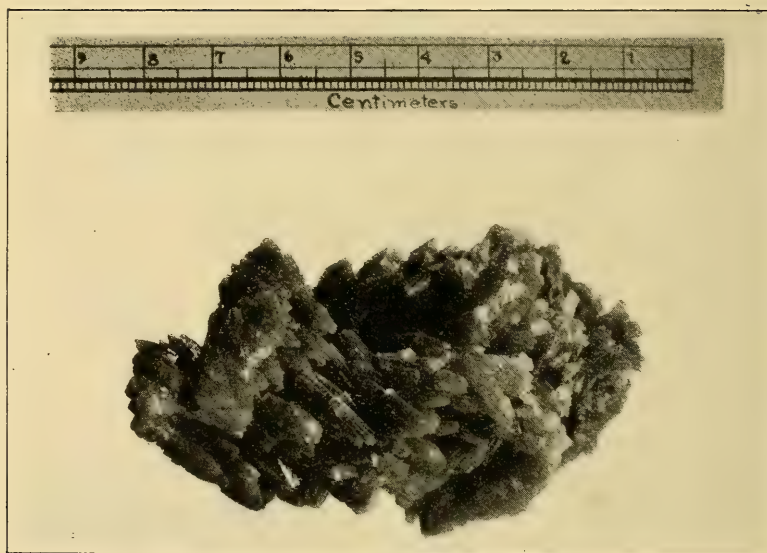
Kaolinite is a basic aluminium silicate with some iron and organic matter.

It occurs in small scalelike pearly monoclinic crystals, more commonly in compact or loose masses of a claylike nature. The color is white, grayish, yellowish and sometimes brownish, bluish or reddish. The common massive material is plastic and unctuous to the touch.

¹Nevius, J. N. Talc industry of St Lawrence county, N. Y. N. Y. state mus. 51st an. rep't. 1897. 1:119-27.



1 Pyrophyllite, Lincoln county, Ga.



2 Pyromorphite, Ems, Germany

Kaolin is of secondary origin resulting from a decomposition of the feldspars and other silicates. It occurs associated with the feldspars, corundum, topaz, etc. Notable deposits occur in China, Belgium, France, Bavaria and Cornwall. In the United States kaolin is mined in Florida, North Carolina, Delaware, Pennsylvania, and in somewhat poorer quality in Ohio, New Jersey, New York and other states.

As a constituent of porcelain, chinaware, tiling and similar products its importance is constantly increasing.¹

Pyrophyllite (pencil stone) $\text{H}_2\text{Al}_2(\text{SiO}_3)_4$

Pyrophyllite is a basic aluminium silicate.

It occurs in radiated, lamellar or fibrous masses, sometimes compact and smooth, soft and soapy like talc (pl. 36₁). The luster is pearly to dull and the color white, greenish, brownish or yellow.

The compact variety is present in some schistose rocks and the foliated form often occurs associated with cyanite. Pyrophyllite is found in North Carolina, South Carolina and Georgia.

It is extensively used for slate pencils.

Chrysocolla $\text{CuSiO}_3 + 2\text{H}_2\text{O}$

Chrysocolla is a hydrous copper silicate containing 34.3% silica, 45.2% copper oxid and 20.5% water. It is often very impure.

Chrysocolla is found in green to blue masses with an enamel-like texture; sometimes botryoidal; incrusting or filling seams. Impure varieties often occur in earthy masses, green or dull brown in color.

It occurs associated with other copper minerals specially in the upper parts of veins and is to be found in most of the copper producing regions.

It is an ore of copper and is also used for imitation turquoise.

Titano-silicates, Titanates

Titanite (sphene) CaTiSiO_5

Titanite is a calcium titano-silicate often carrying iron in varying amounts and sometimes manganese and yttrium.

¹ For an exhaustive treatise on this subject see N. Y. state mus. Bul. 35, 1900.

The crystals of titanite are monoclinic and very varied in form; commonly of a wedge-shaped or tabular type (fig. 235) but often prismatic in habit. Compact massive forms also occur but lamellar varieties are rare. The luster is adamantine or resinous and the color usually brown to black, yellow or green, rarely rose-red.

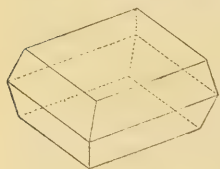


Fig. 235
Titanite

Titanite occurs as an accessory rock-forming mineral in many igneous rocks, mostly of the acidic feldspathic type and is more common in plutonic granular than in the volcanic forms.

It is found in basic hornblende granites, syenites and diorites and is very characteristic of the nephelin schists, gneisses, etc.; also in granular limestone and in beds of iron ore. It is commonly associated with pyroxene, amphibole, wernerite, zircon, apatite, etc. and when found in cavities in granite and gneiss often accompanies orthoclase and quartz.

Handsome specimens are to be found in Ottawa and Renfrew counties, Canada, and in New York in the Lake George region of Essex county and in St Lawrence, Lewis, Orange and Putnam counties. Transparent varieties are cut for gems.

NIOBATES, TANTALATES

Columbite, tantalite

The species columbite, an iron and manganese niobate, and tantalite, an iron tantalate, grade into each other chemically to such an extent that it is impossible to definitely separate the two species. The normal formula for columbite is $(\text{Fe}, \text{Mn})\text{Nb}_2\text{O}_6$ and that for normal tantalite is FeTa_2O_6 . The iron and manganese vary widely and tin and wolfram are also often present in small amounts.

The crystals which are orthorhombic are of varied habit, sometimes occurring in short prismatic forms or in tabular prismatic crystals flattened parallel to the macropinacoid. Heart-shaped twins are quite common. It also occurs massive. The luster is submetallic, often very brilliant, and the color black in opaque varieties or brown in the more translucent occurrences. It is frequently iridescent, particularly on the surfaces produced by cleavage, which occurs in two directions at right angles.

Columbite often occurs in granite and pegmatite veins, in mica, and, in the Greenland locality, in cryolite; it has been found in gold washings in the Urals. In the United States it is found in Maine, New Hampshire, Massachusetts, Connecticut, New York, Pennsylvania, Virginia, North Carolina, Colorado, South Dakota and California.

PHOSPHATES, ARSENATES, VANADATES, ANTIMONATES

Monazite $(\text{Ce,La,Di})\text{PO}_4$

Monazite is a phosphate of the cerium metals, with some thorium and silicon possibly present as mechanical impurities.

It occurs in small monoclinic crystals (fig. 236) often flattened parallel to the orthopinacoid; also in disseminated grains or as sand and sometimes in angular masses. The luster is resinous and the color hyacinth-red, brown to yellow.

Monazite in the form of sand is quite abundant in certain parts of Brazil; it also occurs as a constituent of the gneiss rock of North Carolina and South Carolina.

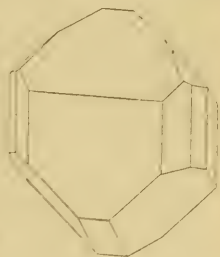


Fig. 236
Monazite

It is the chief source of the thorium which is now extensively used in the manufacture of mantles for incandescent gas fixtures.

Apatite group

Apatite (phosphate rock) $\text{Ca}_5(\text{Cl,F})(\text{PO}_4)_3$

Under this head are included the subdivisions fluor-apatite and chlor-apatite. The former is a calcium phosphate with calcium fluorid and the latter a calcium phosphate with calcium chlorid. Intermediate compounds contain both fluorin and chlorin in varying amounts.



Fig. 237
Apatite

Apatite crystallizes in the pyramidal group of the hexagonal system. The crystals are prismatic in habit commonly terminated by the unit pyramid (fig. 237) and sometimes with the additional modification of the base; occasionally the prismatic crystals are short or tabular and show the modification of the third order pyramid (as in specimens from Knapenwand in the Tyrol). Compact massive varieties have a globular or reniform structure and are often found in rocklike

masses or nodules not unlike common limestone. The luster is vitreous to resinous and the color varies widely from sea-green, bluish green, brown or flesh-red, in the commoner occurrences, to transparent violet, yellow or colorless and opaque white or gray in the less common forms.

VARIETIES

Ordinary. Crystallized or granular massive material as described above.

Phosphorite. Fibrous concretionary and partly scaly masses.

Osteolite. Mostly altered and impure apatite of a compact earthy nature and white or gray in color.

RELATED

Phosphate rock. A massive impure phosphatic material chiefly of organic origin, and granular, spongelike or nodular in structure. Here are included the phosphatic limestones, guano deposits and bone beds from which is extracted material of considerable importance in the manufacture of fertilizers.

Apatite occurs in a great variety of formations but is most common in metamorphic crystalline rocks particularly in granular limestone, in gneiss, syenite, mica schist and in beds of iron ore. As an accessory rock mineral it has a wide distribution. It is found in many igneous rocks, the larger crystals being characteristic of granite and pegmatite, where it is associated with quartz, feldspar, tourmalin, muscovite, beryl, etc.

Besides many foreign localities apatite occurs in extensive deposits in the Laurentian gneiss of Canada associated with calcite, pyroxene, amphibole, titanite, etc. It is found in Maine, New Hampshire, Massachusetts, Connecticut, and in New York, in St Lawrence, Jefferson, Essex and Orange counties; also in Pennsylvania and North Carolina. Extensive deposits of phosphate rock occur in eastern South Carolina and Florida.

Apatite in the form of phosphate rock is largely used for fertilizers. The purer material is employed in the manufacture of phosphorus.

Pyromorphite (green lead ore) $(\text{PbCl})\text{Pb}_4(\text{PO}_4)_3$

Pyromorphite is a phosphate of lead with lead chlorid, often with some arsenic, iron or calcium. With a larger proportion of arsenic it passes into mimetite.



1 Mimetite, Cornwall, England



2 Wavellite, Garland county, Ga.

It occurs in hexagonal crystals of the pyramidal group, prismatic in habit, often in rounded or barrel-shaped forms or in parallel and branching groups (pl. 36₂), less frequently in globular and reniform masses with a subcolumnar structure. The luster is resinous and the color usually some shade of green, yellow or brown, also grayish white or milk-white.

Pyromorphite occurs principally in veins with galena and other lead minerals. It is found in Saxony, Bohemia and Nassau and in several places in England and Scotland. In the United States it occurs in Maine, Pennsylvania, North Carolina and at Ossining N. Y.

Mimetite $(\text{PbCl})(\text{AsO}_4)_3$

Mimetite is an arsenate of lead with lead chlorid. With the replacement of arsenic by phosphorus it grades into pyromorphite; calcium also frequently replaces part of the lead.

The crystals of mimetite are hexagonal-pyramidal and resemble those of pyromorphite; they show, however, a marked tendency toward the production of rounded, globular aggregates (pl. 37₁). The mineral also occurs in mammillary crusts. The luster is resinous and the color yellow to brown or white. Its occurrence is similar to that of pyromorphite.

Vanadinite $(\text{PbCl})(\text{VO}_4)_3$

Vanadinite is a vanadate of lead with lead chlorid. Phosphorus is also often present in small amounts; also arsenic, both of which replace some of the vanadium.

The crystals are like those of pyromorphite and mimetite, often with hollow or cavernous faces on the basal plane, and sometimes showing the modification of the third order pyramid (fig. 238). The luster is resinous and the color deep red, brown to yellow.

Vanadinite abounds in the mining regions of Arizona and New Mexico where it is associated with wulfenite.

Vanadinite is a source of vanadium salts, which are used in dyeing fabrics, and for the production of vanadium bronze, vanadium ink, etc.

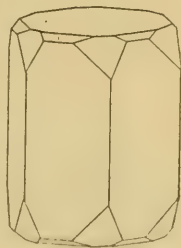


Fig. 238
Vanadinite

Olivenite $\text{Cu}_2(\text{OH})\text{AsO}_4$

Olivenite is a basic arsenate of copper. It occurs in small orthorhombic crystals of prismatic habit and often acicular; also in velvety or drusy masses of fibrous crystals and in globular forms. The luster is adamantine to vitreous and the color olive-green of various shades passing to brown and sometimes almost black, more rarely yellow or grayish white.

It is found in Cornwall, Devonshire, the Tyrol, the Ural mountains, Chile and in the Tintic district of Utah.

Libethenite $\text{Cu}_2(\text{OH})\text{PO}_4$

Libethenite is a basic copper phosphate. It occurs in small orthorhombic crystals closely resembling those of olivenite in form and luster; the color is in general somewhat darker than that of olivenite.

Lazulite

Lazulite is a basic phosphate of aluminium, iron and magnesium.

It occurs in monoclinic crystals of pyramidal habit and in granular to compact masses. The luster is vitreous and the color deep sky-blue.

It occurs in veins in clay slate, quartzite, etc. and is found in Salzberg, Styria, Sweden and in North Carolina and Georgia.

Vivianite (blue iron earth) $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$

Vivianite is a hydrous phosphate of ferrous iron.

It occurs in monoclinic prismatic crystals, often in stellate groups; also as an earthy material replacing organic remains as bones, shells, etc. The luster is vitreous to dull. The unaltered material is colorless but gradually becomes blue or bluish green on exposure to air.

It occurs associated with pyrrhotite and pyrite in veins of copper or tin, in beds of clay or associated with limonite; also in cavities of fossils or buried bones.

Vivianite occurs in the United States in New Jersey, Virginia and Kentucky.

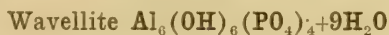
Erythrite (cobalt-bloom) $\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$

Erythrite is a hydrous arsenate of cobalt.

It occurs in monoclinic prisms striated vertically and sometimes in stellate groups. Small globular and incrusting forms

with drusy or velvety surfaces are of frequent occurrence as well as an earthy variety pink in color. The luster is vitreous to adamantine, pearly on some faces, also dull or earthy. The color is crimson-red to peach-red.

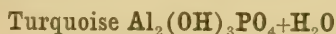
It is found in Saxony, Baden, Norway and in the United States in Pennsylvania, Nevada and California.



Wavellite is a hydrous basic phosphate of aluminium.

Distinct orthorhombic crystals are rare. The mineral is commonly found in hemispheric or globular aggregates of radiating fibrous crystals (pl. 37₂). Stalactitic forms also occur. The luster is vitreous and the color white, yellow or green, occasionally brown, blue or black.

It is found in Devonshire, Saxony, Bohemia, Brazil and in Pennsylvania, Arkansas and North Carolina.



Turquoise is a hydrous basic phosphate of aluminium with some copper, to which it owes its color.

It occurs in sky-blue to green nodules, veins or rolled masses with a dull or waxlike luster; also stalactitic or incrusting.

Turquoise occurs in porphyritic trachyte and in a clay slate which, in the Persian locality, is found penetrated by trachyte. It was formerly extensively mined in Persia; recently, however, important workings in New Mexico have been reopened and are producing very good material. Localities are also known in Arizona, California, Colorado and Nevada.

Turquoise is used as a gem.



Torbernite is a hydrous phosphate of uranium and copper.

It occurs in small tabular tetragonal crystals often extremely thin, of a bright green color and pearly luster. Less frequently it occurs in pyramidal forms or in foliated micaceous aggregates.

It has been found in Cornwall, Saxony and Bohemia.

Autunite (lime uranite) $\text{Ca}(\text{UO}_2)_2\text{P}_2\text{O}_8+8\text{H}_2\text{O}$

Autunite is a hydrous phosphate of uranium and calcium.

It is found in tabular orthorhombic crystals very similar to those of torbernite but lemon-yellow or sulfur-yellow in color.

It occurs in Connecticut, North Carolina and in the Black hills of South Dakota.

BORATES

Boracite $\text{Mg}_7\text{Cl}_2\text{B}_{16}\text{O}_{30}$

Boracite is a chloro-borate of magnesium.

The crystals are of the tetrahedral class of the isometric system and are commonly small and cubic (fig. 239), tetrahedral

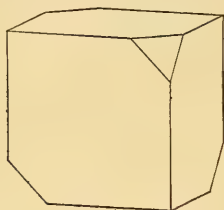


Fig. 239

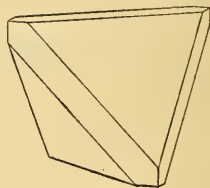


Fig. 240

Boracite

(fig. 240), octahedral or dodecahedral in habit; these usually occur isolated embedded in gypsum, anhydrite or salt. A massive variety occurs in snow-white, soft and powdery masses. The crystals are colorless, white to gray, yellow or green and vitreous to adamantine in luster.

Boracite is found associated with other minerals which have been deposited from solution and occurs in many parts of Europe notably at Stassfurt, Prussia.

Colemanite $\text{Ca}_2\text{B}_6\text{O}_{11}+5\text{H}_2\text{O}$

Colemanite is a hydrous borate of calcium often occurring in monoclinic crystals, short prismatic in habit, and somewhat resembling those of datolite, also in cleavable to granular and compact masses. Colemanite is commonly white or colorless and of a vitreous to dull luster.

Under this species are included:

Priceite. A massive variety, white and chalky in appearance and loosely compacted in structure.

Pandermite. A white variety in firm, compact, porcelainlike masses.

Colemanite is found quite abundantly in California, Nevada and Oregon. Pandermite is mined near Panderma in Turkey. Colemanite is an important source of the borax of commerce.

Borax (tinkal) $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$

Borax is a hydrous borate of sodium.

It occurs in sharp, well formed monoclinic crystals transparent to opaque resembling those of pyroxene in habit. The color is white to gray sometimes inclining to greenish or bluish and the luster is vitreous to dull.

Borax is present in solution in many lakes of a saline or alkaline nature and is found crystallized in the mud at the bottom and in deposits in the surrounding marshes. Deposits of considerable importance occur in Nevada and California.

It is used in many industries such as soap, glass making etc., as a preservative and in washing, bleaching and antiseptic preparations.

Ulexite $\text{NaCaB}_5\text{O}_{13} \cdot 8\text{H}_2\text{O}$

Ulexite is a hydrated borate of sodium and calcium.

It occurs in loose rounded masses of fibrous crystals, white in color and with a silky luster.

Its occurrence is similar to colemanite and borax and it is found in Nova Scotia and Chile as well as in the borax localities of Nevada and California.

It is much used in the manufacture of borax.

URANATES

Uraninite (pitchblende)

Uraninite is a uranate of uranyl, lead, usually thorium (or zirconium) and frequently metals of the lanthanum and yttrium groups. The relation between the bases, however, varies so widely that no definite formula can be given.

It rarely occurs in isometric crystals of octahedral habit but is commonly found in botryoidal or granular masses pitchlike in luster and appearance and generally black in color.

Uraninite occurs as a primary constituent of granitic rocks and as a secondary mineral with silver, lead and copper ores. The main supply is obtained from Bohemia. It is mined, how-

ever, in Colorado and is found to some extent in North Carolina, South Carolina, Texas and in the Black hills of South Dakota.

It is the principal source of the uranium salts used in painting on porcelain and in the manufacture of fluorescent glass.

SULFATES, CHROMATES, ETC.

Barite (heavy spar, barytes) BaSO_4

Barite is the sulfate of barium, sometimes containing strontia, silica, clay, etc. as impurities.

It occurs in orthorhombic crystals which are often tabular in habit (fig. 241, 242); these are sometimes united in divergent



Fig. 241



Fig. 242
Barite

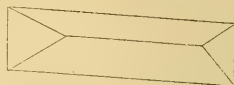


Fig. 243

groups giving the crested appearance shown in pl. 38₁, and passing by insensible gradations into straight or curved laminated masses. Crystals with prominent dome faces (fig. 243) are also frequent. Massive forms are of a granular, fibrous, earthy, stalactitic or nodular structure. Barite cleaves easily parallel to the basal and prismatic faces. The color is commonly white or light shades of yellow, brown, red or blue; the luster is vitreous to pearly.

Barite frequently occurs associated with metallic deposits, particularly with lead, copper, iron, silver, manganese and cobalt. It is mined in North Carolina, Virginia and Missouri, and is also found in Connecticut, Tennessee, Kentucky, Illinois and in Jefferson and St Lawrence counties, of New York. It is also mined in Germany and Hungary.

White varieties of barite are ground and used as an adulterant of white lead and to give weight and body to paper and certain kinds of cloth. The colored varieties are sometimes polished for ornamental purposes.

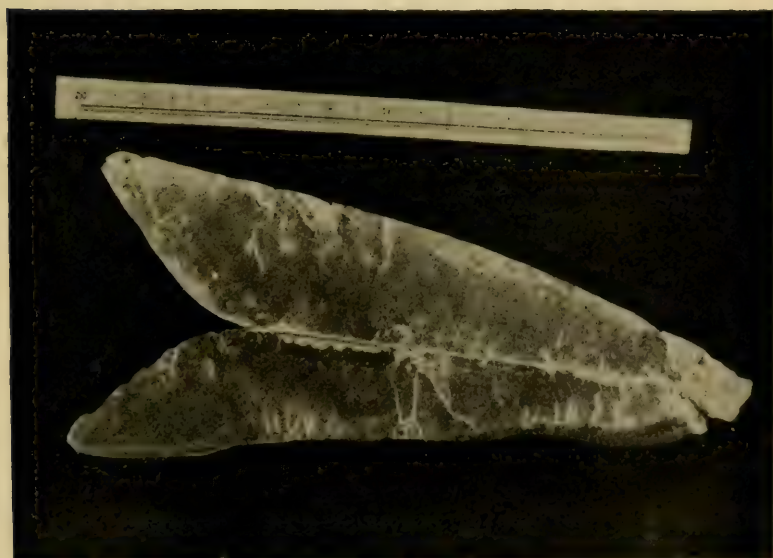
Anhydrite CaSO_4

Anhydrite is an anhydrous calcium sulfate.

It is rarely found in orthorhombic crystals; massive forms are often characterized by rectangular cleavage in three directions.



1 Barite, Hartz, Germany



2 Gypsum, Paris, France

Fibrous, granular and marblelike masses occur, sometimes exhibiting a sugarlike appearance on the fracture. The color is commonly white or gray, often bluish, reddish or brick-red. The luster is vitreous inclining to pearly.

Anhydrite occurs associated with rock salt, gypsum and limestones of various ages. It is found in New Brunswick and Nova Scotia and to a limited extent at Lockport N. Y. and in eastern Pennsylvania and Tennessee.

Anglesite PbSO_4

Anglesite is a sulfate of lead containing 26.4% sulfur trioxid and 73.6% lead oxid.

The crystals are orthorhombic and of varied habit. Massive forms are extremely common, the mineral frequently forming in concentric layers around a core of galena. Anglesite is white, gray or more rarely bluish or yellowish in color; the crystals are often transparent and colorless. The luster is adamantine to vitreous.

It is a frequent decomposition product of galena with which it is commonly associated and often alters to cerussite. It is found throughout the United States in the lead regions notably in Pennsylvania, Missouri, Wisconsin and Colorado. Extensive deposits occur in Mexico and Australia.

It is mined with other lead minerals as an ore of lead.

Celestite SrSO_4

Celestite is a sulfate of strontium sometimes containing small amounts of calcium and barium.

It crystallizes in the orthorhombic system in forms generally similar in type to those of barite, often tabular parallel to the base or prismatic to the macro or brachy axes (fig. 244). Fibrous massive forms occur with a parallel or radiated silky structure; also cleavable masses and more rarely granular varieties. In color celestite varies from white to pale blue, sometimes reddish; the crystals are often transparent and colorless. The luster is vitreous to pearly.

Celestite is of frequent occurrence in limestone and sandstone, in beds of gypsum, rock salt, etc.; and in volcanic regions asso-

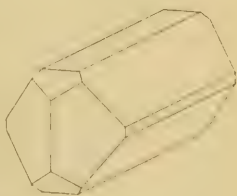


Fig. 244
Celestite

ciated with sulfur and other eruptive minerals. Beautiful crystals have been obtained from Girgenti, Sicily. It also occurs at several localities on Lake Erie; at Lockport, Chaumont bay, Rossie and Schoharie N. Y.; in Pennsylvania, West Virginia, Tennessee, Kansas, Texas and California, and at Kingston Canada.

As a source of strontium nitrate, celestite is much used in the manufacture of fireworks.

Crocoite PbCrO_4

Crocoite is a lead chromate occurring in monoclinic crystals of prismatic habit and in imperfectly columnar and granular masses. It is of a bright hyacinth-red to orange-yellow color. The luster is adamantine.

Brochantite $4\text{CuO} \cdot \text{SO}_3 \cdot 3\text{H}_2\text{O}$

Brochantite is a basic sulfate of copper commonly found in acicular orthorhombic crystals or drusy crusts of an emerald-green or blackish green color and vitreous luster.

Gypsum (selenite, alabaster) $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

Gypsum is a hydrous calcium sulfate.

The crystals are monoclinic and commonly quite simple in form, fig. 245 and 246 representing types of common occurrence.



Fig. 245

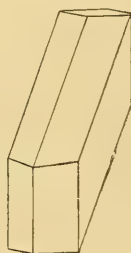


Fig. 246

Gypsum

Twins of the arrowhead form shown in pl. 38₂ are quite frequent. Massive forms have a foliated, lamellar or granular structure and a fibrous variety known as satin spar is often of marked beauty. Easy cleavage parallel to the clinopinacoid yields thin polished plates. The color varies from white to gray, flesh-red, yellow or light blue. The luster is pearly to sub-vitreous.

VARIETIES

Selenite. A colorless transparent variety usually in distinct crystals or broad folia.

Fibrous. A coarse or fine fibrous variety, translucent and silky in luster.

Alabaster. A compact, fine grained gypsum much used for carved objects.

Rock gypsum. An earthy dull colored variety often containing clay, calcium carbonate or silica as an impurity.

Extensive deposits of gypsum have resulted from the evaporation and concentration of ancient seas and landlocked waters. Gypsum is also produced by volcanic action and from the decomposition of limestone by sulfuric acid. In New York gypsum is found throughout the rocks of the Salina group in considerable quantities associated with halite. Deposits also occur in Ohio, Illinois, Virginia, Tennessee, Kansas and Arkansas and to a considerable extent in Nova Scotia.

Gypsum is burned and ground for plaster of paris and when ground from the raw material is of considerable value as a fertilizer. Alabaster and, to some extent, satin spar are used for carved ornamental objects.

Epsomite (epsom salt) $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$

Epsomite is a hydrous magnesium sulfate. It is usually found in white botryoidal masses and delicately fibrous crusts and is characterized by its bitter saline taste.

Alunite (alum stone) $\text{K}(\text{AlO})_2(\text{SO}_4)_2 \cdot 3\text{H}_2\text{O}$

Alunite is a hydrous sulfate of aluminium and potassium.

It crystallizes in rhombohedrons closely resembling cubes. It also occurs in massive forms of fibrous, granular or impalpable structure. The color is generally white, often shading to grayish or reddish. The luster is vitreous to pearly.

It occurs as seams in rocks of a trachytic character where it has been formed by the action of sulfur dioxide and steam. It is found in Rosita hills, Col.

Alunite is used in the production of alum.

TUNGSTATES. MOLYBDATES

Wolframite (wolfram) $(\text{Fe,Mn})\text{WO}_4$

Wolframite is a tungstate of iron and manganese in which these metals are present in varying amounts.

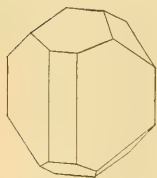


Fig. 247
Wolframite

The crystals are monoclinic, of the general type shown in fig. 247. These are commonly tabular parallel to the orthopinacoid; also prismatic. Twins are quite frequent; granular or columnar masses also occur. Perfect cleavage parallel to the clinopinacoid is characteristic as well as parting planes parallel to the orthopinacoid and hemi-orthodome. The color is a dark grayish or brownish black and the luster is submetallic.

Wolframite occurs associated with tin ores and other metallic minerals notably in the Cornwall and German mines. It is also found in New South Wales and Bolivia and in Connecticut, North Carolina, Missouri and Dakota.

It is used in the manufacture of tungsten steel and as a source of the tungsten salts, which are of considerable importance in dyeing.

Scheelite CaWO_4

Scheelite is a calcium tungstate crystallizing in the pyramidal class of the tetragonal system.

The crystals are pyramidal in habit (fig. 248), more rarely tabular. These often occur in drusy crusts. The color is white or light shades of yellow, brown, red, rarely green. The luster is vitreous tending to adamantine.

Scheelite occurs in crystalline rocks associated with cassiterite, fluorite, topaz, apatite, molybdenite or wolframite, incrusting or in quartz, and sometimes associated with gold. It is of comparatively rare occurrence but is found at Monroe and Trumbull Ct. and in South Carolina, Nevada, Idaho and Colorado.

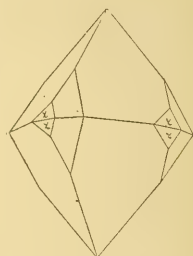


Fig. 248
Scheelite

Wulfenite PbMoO_4

Wulfenite is a lead molybdate crystallizing in the pyramidal class of the tetragonal system.

The crystals are commonly thin tabular in habit of the general type shown in fig. 249; octahedral or prismatic forms are much

less frequent, as are also granular massive forms. The commoner colors include a wax-yellow, orange to bright red and brown; an olive-green variety is rather rare.

Wulfenite occurs in veins associated with other ores of lead particularly vanadinite and pyromorphite. In the

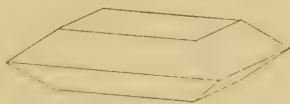


Fig. 249
Wulfenite

United States it is principally found in Arizona and New Mexico though smaller deposits have been found in Massachusetts, near Ossining N. Y., in Pennsylvania, Missouri, Wisconsin, Nevada, Utah and California.

HYDROCARBON COMPOUNDS

With few exceptions, hydrocarbon compounds are not homogeneous substances and hence are not to be classed as definite mineral species. On the other hand, several substances belonging to this division have acquired so much importance from an economic point of view that it is thought best to briefly describe them here.

Amber

Amber occurs in irregular masses which break with a conchoidal fracture. It has a resinous luster, is usually yellowish in color and is transparent to translucent. Amber is of vegetable origin and is derived from the fossilization of gums or resins, a fact which is frequently shown by the presence of insects in it.

It is found in Denmark and Sweden, on the Prussian coast of the Baltic and in Russian Baltic provinces. It is used for jewelry and for mouthpieces of pipes.

Petroleum

Members of this series grade from a thin yellow fluid to dark brown or nearly black viscid oils; the greenish brown colors are the most common. The density also varies and it may be generally stated that the light varieties are richest in volatile constituents while the heavier and darker kinds produce the benzins on distillation.

Petroleum is found in rocks of various ages from the Lower Silurian to the present epoch but is most abundant in argillaceous shales, sands and sandstones. Considerable petroleum is furnished by the regions of western Pennsylvania, southwestern New York and Ohio. It is also largely produced in the neighborhood of the Caspian sea and occurs in many other localities.

Asphaltum

Asphaltum or mineral pitch is an amorphous mixture of hydrocarbons, for the most part oxygenated. It is characterized by a black color and dull luster and melts at about 100° F.

Asphaltum is not associated with rocks of any particular age but is most abundant in formations containing bituminous material or vegetable remains. It is found in the region of the Dead sea; in Trinidad, where it forms a lake about a mile and a half in circuit; and in various places in South America and elsewhere.

Its use for paving purposes is well known.

Uintaite (gilsonite). A variety of asphalt found in considerable deposits in Utah.

Albertite. An amorphous hydrocarbon compound differing from ordinary asphaltum in its very imperfect fusibility and in the fact that it is only partially soluble in oil of turpentine. It has a brilliant luster and is jet black in color. Albertite occurs in the rocks of the Lower Carboniferous in Nova Scotia.

Mineral coal

Coal is a compact massive substance consisting mainly of oxygenated hydrocarbons. It is black, grayish black or brownish black in color, occasionally iridescent, and has a luster varying from dull to brilliant.

Coal owes its origin to the gradual alteration of organic deposits, chiefly vegetable. It occurs in beds interstratified with shales, sandstones and conglomerates, sometimes forming distinct layers of varying thickness.

Anthracite. Anthracite or hard coal is characterized by a bright, often submetallic luster and is iron-black in color, frequently iridescent. It contains comparatively little volatile matter.

Anthracite beds occur in the formations east of the Alleghany range, which in Pennsylvania reach a thickness of 3300 feet.

Bituminous coal. Bituminous coal differs from the above chiefly in the higher percentage of volatile hydrocarbon oils contained in it. Bituminous coal may be classed as:

- 1 caking or coking coal
- 2 noncaking coal
- 3 cannel coal



1 Iron (meteorite), Schwarzenberg, Saxony

Brown coal or lignite. Brown coal contains more oxygen than bituminous coal, is compact or earthy and yields a brownish black powder.

For a more detailed discussion of the occurrence and geologic relations of coal deposits the reader is referred to New York state museum bulletin 19 or to some work on economic geology.

• **METEORITES**

Considerable knowledge regarding the probable character of heavenly bodies other than the earth is furnished by the meteorites or fallen stars. These fragments from planetary space contain a number of minerals which are identical with terrestrial species, as well as several which have not, up to this time, been found on the earth.

They have been classified into three groups:

1 Siderites. Metallic masses composed principally of iron alloyed with nickel and some manganese and cobalt. Polished surfaces of siderites when etched with dilute nitric acid develop a series of intersecting lines or bands which are known as Widmanstätten figures (pl. 39₁).

2 Siderolites. Masses of a spongy, cellular character composed partly of iron and partly of stony material and frequently containing embedded grains of chrysolite.

3 Aerolites. Masses composed principally of stony material in the form of silicates including chrysolite, enstatite and minerals in the pyroxene group.

Meteorites are of universal distribution and can not be said to be characteristic of any locality.

APPENDIX

GLOSSARY OF CRYSTALLOGRAPHIC TERMS

Acicular. Needlelike in structure.

Arborescent. With a branching structure like a tree or plant.

Axes. Imaginary lines drawn within a crystal for the purpose of studying the relation of its planes.

Axial ratio. The relations between the lengths of axes which are not interchangeable as determined by the intercepts of a prominent pyramid face.

Basal plane or base. A plane which truncates the crystal parallel to the basal axes.

Biaxial crystals. A term used to include in an optical division crystals of the orthorhombic, monoclinic and triclinic systems.

Binary. Twofold.

Bladed structure. Composed of bundles of broad flat crystals resembling the blades of knives.

Botryoidal. Derived from a Greek word meaning a bunch of grapes.

Brachyaxis. The shorter of the two basal axes in the orthorhombic and triclinic systems. The term brachy is derived from a Greek word meaning short.

Brachydomes. Domes or horizontal prisms parallel to the brachyaxis.

Brachypinacoid. A pinacoidal plane parallel to the vertical and brachy axes.

Brachyprisms, brachypyramids. Crystal forms the planes of which are more nearly parallel to the brachyaxis than those of the form which determines the axial ratio. [See p. 32, fig. 124]

Capillary crystals. Extremely elongated individuals resembling hairs or threads.

Clinoaxis. The axis which in the monoclinic system is oblique to the plane of the other two but is perpendicular to one of the latter.

Clinodomes. Domes or horizontal prisms the faces of which are parallel to the clinoaxis.

Clinopinacoid. A pinacoid parallel to the vertical and clino axes.

Clinoprisms, clinopyramids. Crystal forms the faces of which are more parallel to the clinoaxis than the form which determines the axial ratio.

Columnar structure. Composed of aggregates of elongated crystals resembling columns.

Coralloidal. Branching and interlacing forms resembling coral.

Crystalline aggregate. An aggregate of imperfect crystals.

Cube. An isometric form bounded by six rectangular faces. In ideal crystals the faces are square.

Dendritic. See Arborescent.

Dihexagonal. Presenting in section, a 12 sided symmetric figure closely related to a hexagon. [See p. 26, fig. 98]

Diploids. Isometric forms bounded by 24 four sided faces. The diploid is so named from the fact that the faces are grouped in pairs.

Ditetragonal. Presenting in section an eight sided symmetric figure somewhat resembling an octagon but more closely related to a square.

Divergent. Composed of elongated crystalline individuals which diverge or radiate from a center.

Dodecahedron. An isometric form bounded by 12 (dodeca) rhombic faces.

Domes. Horizontal prisms which in the orthorhombic, monoclinic and triclinic systems are parallel to one basal axis. The term is derived from the Latin *domus*, a house, to describe their resemblance to a hip roof.

Drusy. Covered with extremely minute crystals producing a roughened surface.

Faces. The bounding surfaces of a crystal.

Fibrous. Composed of slender filaments or fibers.

First order. A term applied in the tetragonal and hexagonal systems to pyramids and prisms the faces of which intersect two basal axes with equal intercepts; any plane of the hexagonal forms is parallel to the third basal axis.

Foliated. Composed of layers of imperfectly formed crystals which may be separated from one another with ease; derived from the Latin *folio*, a leaf.

Geode. A hollow rounded fragment lined with crystals.

Granular structure. Composed of irregular particles or grains.

Habit of crystals. The general preponderance of certain forms in crystals of a given species and from a given locality.

Hemimorphic. Having a dissimilar development of crystal planes on the two extremities.

Hexagonal. Sixfold.

Hexakistetrahedrons. Tetrahedral forms of the isometric system bounded by 24 triangular faces arranged in four groups of six each.

Hexoctaherons. Forms of the normal group of the isometric system bounded by 48 triangular faces. The name derived from the Greek refers to the grouping of the faces in eight groups of six each.

Inclusions. Foreign matter of a solid, liquid or gaseous nature inclosed within the crystal.

Isometric. Presenting the highest degree of symmetry in which the three crystallographic axes are interchangeable. The term is derived from two Greek words meaning equal measure and refers to the ideal development in which the three axes are of equal length.

Isomorphic. Presenting the close chemical and crystallographic relations stated on p. 45.

Macroaxis. The longer of the two basal axes in the orthorhombic and triclinic systems. The term macro is derived from a Greek word meaning long.

Macrodome. A dome or horizontal prism parallel to the macroaxis.

Macropinacoid. A pinacoidal plane parallel to the vertical and the macro axis.

Macroprisms, macropyramids. Crystal forms, the planes of which are more nearly parallel to the macroaxis than those of the form which determines the axial ratio. [See p. 32, fig. 124]

Mammillary structure. Consisting of rounded prominences; the term is derived from the Latin *mamma*, meaning a female breast.

Micaceous structure. In thin leaves which may be separated from one another as typified in the mica group of minerals.

- Octahedron.** A crystal form bounded by eight equilateral, triangular faces; derived from a Greek word meaning eight.
- Orthoaxis.** The axis which, in the monoclinic system, is perpendicular to the plane of the other two.
- Orthodomes.** Domes or horizontal prisms parallel to the orthoaxis.
- Orthopinacoid.** A pinacoid parallel to the vertical and ortho axes.
- Orthoprisms, orthopyramids.** Crystal forms the faces of which are more parallel to the orthoaxis than the form which determines the axial ratio.
- Orthorhombic.** Presenting the symmetry of the orthorhombic system, referable to three uninterchangeable axes which are at right angles to one another. Orthorhombic crystals are characterized by binary symmetry in three directions.
- Pinacoids.** Crystal forms composed of planes parallel to two axes and corresponding in position to the faces of a cube; the term is derived from a Greek word meaning a board.
- Plane.** One of the bounding plane surfaces of a crystal; the term is extended to include the imaginary extension of this bounding surface to meet the axes.
- Prisms.** Crystal forms the planes of which intersect two basal axes and are parallel to a third. Domes as described above may be regarded as horizontal prisms.
- Pseudohexagonal.** Apparently hexagonal; many crystals *seem*, by reason of twinning, to be hexagonal though belonging to a system of lower symmetry.
- Pseudoisometric.** Apparently isometric; note above.
- Pseudomorph.** A substance having the form of one mineral and the composition of another; the term is derived from two Greek words meaning a false form.
- Pyramids.** Crystal forms the planes of which intersect all three axes. In the isometric system forms of this type are designated by special terms such as octahedron, trioctahedron, etc.
- Pyritohedrons.** Isometric forms so named from their common occurrence in the species pyrite.
- Radiated structure.** Consisting of crystalline individuals which radiate from a center.
- Reniform.** Kidney-shaped; from the Latin *renes*, a kidney.
- Reticulated.** Interlaced like a net; from the Latin *reticulum*, a net.
- Rhombohedral.** Hexagonal forms of trigonal symmetry bounded by six rhombic faces.
- Scalenoedrons.** Crystal forms of the tetragonal and hexagonal systems bounded by scalene triangles and presenting in general a somewhat wedgelike shape.
- Second order.** A term applied, in the tetragonal and hexagonal systems, to pyramids and prisms the faces of which are related to those of the corresponding first order forms as shown on p.26, fig.98.
- Sphenoids.** Crystal forms of the tetragonal and orthorhombic systems bounded by four triangular faces and closely related by analogy to the isometric tetrahedron.
- Stalactitic structure.** Consisting of pendant columns or forms resembling icicles.

Stellated structure. Consisting of radiating individuals producing star-like forms.

Striated. Grooved or furrowed in parallel lines.

Striations. Parallel grooves or furrows on the surfaces of crystals.

Symmetry. The regularity in the recurrence of faces and angles of the same kind.

System. One of the six divisions based on symmetry into which all crystals are divided.

Tetragonal. Fourfold.

Tetrahedron. An isometric form bounded by four equilateral triangles; identical with the regular polyhedron of solid geometry.

Tetrahexahedrons. Isometric forms bounded by 24 isosceles triangles, the faces are grouped in six groups of four, each group corresponding to one face of a cube or hexahedron.

Third order. A term applied, in the tetragonal and hexagonal systems, to pyramids and prisms the faces of which are related to those of the corresponding first order forms as shown on p. 27, fig. 102.

Trapezohedrons. Crystal forms of the isometric, tetragonal and hexagonal systems bounded by trapezohedral faces.

Triclinic. Presenting the lowest degree of symmetry and referable to three inclined axes.

Trigonal. Threefold or triangular.

Trisoctahedrons. Isometric forms bounded by 24 triangular faces arranged in eight groups of three, each group corresponding to one of the faces of an octahedron.

Twin crystals. Intergrowths of like crystals of the same substance symmetrically disposed with respect to certain lines but not in parallel position.

Twinning plane. In twin crystals, an imaginary plane common to both individuals.

Uniaxial. A term used to include in an optical division crystals of the tetragonal and hexagonal systems.

Unit form. A prominent crystal form which is arbitrarily chosen from among those of a given species to determine the axial ratio.

Vicinal planes. Low prominences produced on some crystal faces by disturbances during the growth of the crystal or by other causes.

Widmanstätten lines. Lines of crystalline structure developed on the polished surfaces of meteorites by the action of corrosive agents.

LIST OF ELEMENTS

THEIR SYMBOLS AND ATOMIC WEIGHTS

Aluminium	Al	27	Bromin	Br	79.8
Antimony	Sb	120	Cadmium	Cd	111.7
Argon	A	40	Calcium	Ca	39.9
Arsenic	As	74.9	Carbon	C	12
Barium	Ba	137	Cerium	Ce	140
Beryllium	Be	9.1	Cesium	Cs	132.7
Bismuth	Bi	207.5	Chlorin	Cl	35.5
Boron	B	11	Chromium	Cr	52.5

Cobalt	Co	58.7	Palladium	Pd	106.2
Columbium,			Phosphorus	P	31
<i>see</i> Niobium			Platinum	Pl	194.3
Copper	Cu	63.2	Potassium	K	39
Didymium	Di	142	Praseodymium	Pr	140.5
Erbium	Er	166	Rhodium	Rh	104.1
Fluorin	F	19.1	Rubidium	Rb	85.2
Gadolinium	Gd	156	Ruthenium	Ru	103.5
Gallium	Ga	69.9	Samarium	Sm	150
Germanium	Ge	72.3	Scandium	Sc	44
Glucinum,			Selenium	Se	78.9
<i>see</i> Beryllium			Silicon	Si	28
Gold	Au	196.7	Silver	Ag	107.7
Helium	He	4.3	Sodium	Na	23
Hydrogen	H	1	Strontium	Sr	87.3
Indium	In	113.4	Sulfur	S	32
Iodin	I	126.5	Tantalum	Ta	182
Iridium	Ir	192.5	Terbium	Tb	160
Iron	Fe	55.9	Tellurium	Te	125
Lanthanum	La	138	Thallium	Tl	203.7
Lead	Pb	206.4	Thorium	Th	232
Lithium	Li	7	Thulium	Tu	170
Magnesium	Mg	24	Tin	Sn	118
Manganese	Mn	54.8	Titanium	Ti	48
Mercury	Hg	199.8	Tungsten	W	183.6
Molybdenum	Mo	96	Uranium	U	240
Neodymium	Nd	143.6	Vanadium	V	51.1
Nickel	Ni	58.6	Ytterbium	Yb	172.6
Niobium	Nb	93.7	Yttrium	Yt	89
Nitrogen	N	14	Zinc	Zn	65.1
Osmium	Os	191	Zirconium	Zr	90.4
Oxygen	O	16			

THE MINERAL COLLECTION OF THE NEW YORK STATE MUSEUM

Probably no mineral collection, however large and comprehensive in a comparative sense, can be regarded as exhaustive or complete. New minerals are constantly being discovered and new occurrences of known minerals constantly noted, so that as in the collections of every other department of science, a mineral collection is bound to increase to keep pace with the progress of discovery.

The mineralogic student should not lose sight of the fact that though comparatively few of the many hundreds of mineral species known to science are found in sufficient abundance to be of importance in the arts, the discovery of a considerable deposit of a species which is at present considered rare may at any time

raise it to a high rank in commercial importance. A notable instance of the latter case is afforded by the group of gold and silver tellurids developed within the last 10 years at Cripple Creek, Col. Prior to 1892 these minerals were classed among the rare species and were considered valuable only as mineral specimens.

The principal mineral collection of the New York state museum is displayed in vertical cases which line the walls of the mineral section beginning to the left of the entrance to the section. In arrangement the collection follows the order of this guide which is that of J. D. Dana's *System of mineralogy*. The disposition of the principal divisions is as follows:

DIVISION	CASE
Native elements	1
Sulfids, selenids, tellurids etc.	2
Sulfo salts	3
Haloids	
Oxids	4-8
Carbonates	9-13
Silicates	14-22
Titanates	23
Niobates, tantalates	
Phosphates, arsenates, vanadates etc.	24
Borates, uranates	25
Sulfates	
Tungstates, Molybdates	26
Hydrocarbon compounds	

In disposing the specimens in the cases the top and bottom shelves of each case are reserved for the display of large specimens representing the species of the divisions and groups installed in the case and the five intermediate shelves for the smaller specimens arranged in consecutive order. The swinging card catalogue installed in the spaces between the cases is practically exhaustive, the species represented in the cases being indicated by the letter w (wall cases) and the number which in every instance precedes the species name corresponding to a number placed in the upper left corner of the specimen label; these numbers also correspond to the numbered species of Dana's *System of mineralogy* cited above.

In every instance the most characteristic specimens under each species are to be found in the front row and are therefore best available for detailed study; the back row contains duplicates, massive specimens, and in general, material requiring less close examination. In most instances where the crystallization is of interest and importance wooden models are placed at the head of the species; these are followed by the best examples of crystallization available, crystalline masses and massive forms following the order given in the descriptive text.

An introductory collection illustrating the text of part 1 of this guide is displayed in the table cases of the southern half of the mineralogic section.

The student is also referred to a collection of minerals of economic importance at present displayed in the table cases of the northern half of the mineralogic section. The material here displayed is grouped under the following divisions:

Metalliferous division	Nonmetalliferous division (<i>cont'd</i>)
A Metalliferous ores 1 Arsenic antimony and bismuth minerals 2 Gold minerals 3 Silver minerals 4 Mercury minerals 5 Copper minerals 6 Lead minerals 7 Zinc and cadmium minerals 8 Tin minerals 9 Nickel minerals 10 Uranium and chromium minerals 11 Iron minerals 12 Manganese minerals 13 Aluminium minerals	2 Salt, potash, soda, borax and alum 3 Magnesium, strontium, titanium and thorium compounds 4 Plaster of paris 5 Substances used in the manufacture of chemical compounds C Ceramic materials 1 Porcelain, earthenwares and bricks 2 Pottery and glassware D Refractory materials 1 Graphite 2 Asbestos 3 Mica
Nonmetalliferous division B Substances used for chemical purposes 1 Sulfur, sulfuric and hydrofluoric acids	E Materials of physical application 1 Abrasives 2 Graphic materials 3 Pigments 4 Fertilizers

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¹This list is confined to works in English and could be materially added to should the student wish to consult French and German publications.

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University of the State of New York

New York State Museum

MUSEUM PUBLICATIONS

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All publications are in paper covers, unless binding is specified.

Museum annual reports 1847-date. *All in print to 1892, 50c a volume, 75c in cloth; 1892-date, 75c, cloth.*

These reports are made up of the reports of the director, geologist, paleontologist, botanist and entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

Geologist's annual reports 1881-date. Rep'ts 1, 3-13, 17-date, O.; 2, 14-16, Q.

The annual reports of the early natural history survey, 1836-42 are out of print. Reports 1-4, 1881-84 were published only in separate form. Of the 5th report 4 pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891), 13th (1893) are omitted from the 45th and 47th museum reports.

Separate volumes of the following only are available.

Report	Price	Report	Price	Report	Price
12 (1892)	\$.50	16	\$1	19	\$.40
14	.75	17	.75	20	.50
15	1	18	.75		

In 1898 the paleontologic work of the State was made distinct from the geologic and will hereafter be reported separately.

Paleontologist's annual reports 1899-date.

See fourth note under Geologist's annual reports.

Bound also with museum reports of which they form a part. Reports for 1899 and 1900 may be had for 20c each. Beginning with 1901 these reports will be issued as bulletins.

Botanist's annual reports 1869-date.

Bound also with museum reports 22-date of which they form a part; the first botanist's report appeared in the 22d museum report and is numbered 22.

Reports 22-41, 48, 49, 50 and 52 (Museum bulletin 25) are out of print; 42-47 are inaccessible. Report 51 may be had for 40c; 53 for 20c; 54 for 50c. Beginning with 1901 these reports will be issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have been published in volumes 1 and 3 of the 48th museum report and in volume 1 of the 49th, 51st and 52d reports. The botanical part of the 51st is available also in separate form. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and combined with others more recently prepared and constitute Museum memoir 4.

Entomologist's annual reports on the injurious and other insects of the State of New York 1882-date.

Bound also with museum reports of which they form a part. Beginning with 1898 these reports have been issued as bulletins. Reports 3-4 are out of print, other reports with prices are:

Report	Price	Report	Price	Report	Price
1	\$.50	8	\$.25	13	\$.10
2	.30	9	.25	14 (Mus. bul. 23)	.20
5	.25	10	.35	15 (" 31)	.15
6	.15	11	.25	16 (" 36)	.25
7	.20	12	.25	17 (" 53)	.30

Reports 2, 8-12 may also be obtained bound separately in cloth at 25c in addition to the price given above.

Museum bulletins 1887–date. O. *To advance subscribers, \$2 a year or 50c a year for those of any one division: (1) geology, including economic geology, general zoology, archeology and mineralogy, (2) paleontology, (3) botany, (4) entomology.*

Bulletins are also found with the annual reports of the museum as follows:

<i>Bulletins</i>	<i>Report</i>	<i>Bulletins</i>	<i>Report</i>	<i>Bulletins</i>	<i>Report</i>
12–15	48, v. 1	20–25	52, v. 1	35–36	54, v. 2
16–17	50 “	26–31	53 “	37–44	“ v. 3
18–19	51 “	32–34	54 “	45–48	“ v. 4

The letter and figure in parenthesis after the bulletin number indicate the division and series number. G=geology, EG=economic geology, Z=general zoology, A=archeology, M=mineralogy, P=paleontology, B=botany, E=entomology, Misc=miscellaneous.

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- 1 (Z1) Marshall, W: B. Preliminary List of New York Unionidae. 20p. Mar. 1892. 5c.
- 2 (B1) Peck, C: H. Contributions to the Botany of the State of New York. 66p. 2pl. May 1887. [35c]
- 3 (EG1) Smock, J: C. Building Stone in the State of New York. 152p. Mar. 1888. *Out of print.*
- 4 (M1) Nason, F. L. Some New York Minerals and their Localities. 20p. 1pl. Aug. 1888. 5c.
- 5 (E1) Lintner, J. A. White Grub of the May Beetle. 32p. il. Nov. 1888. 10c.
- 6 (E2) ——— Cut-worms. 36p. il. Nov. 1888. 10c.

Volume 2. 4 nos. [\$1.50] in cloth

- 7 (EG2) Smock, J: C. First Report on the Iron Mines and Iron Ore Districts in New York. 6+70p. map. June 1889. *Out of print.*
- 8 (B2) Peck, C: H. Boleti of the United States. 96p. Sep. 1889. [50c]
- 9 (Z2) Marshall, W: B. Beaks of Unionidae Inhabiting the Vicinity of Albany, N. Y. 24p. 1pl. Aug. 1890. 10c.
- 10 (EG3) Smock, J: C. Building Stone in New York. 210p. map. tab. Sep. 1890. 40c.

Volume 3. 5 nos.

- 11 (EG4) Merrill, F: J. H. Salt and Gypsum Industries in New York. 92p. 12pl. 2 maps, 11 tab. Ap. 1893. 40c.
- 12 (EG5) Ries, Heinrich. Clay Industries of New York. 174p. 2pl. map. Mar. 1895. 30c.
- 13 (E3) Lintner, J. A. Some Destructive Insects of New York State; San José Scale. 54p. 7pl. Ap. 1895. 15c.
- 14 (G1) Kemp, J. F. Geology of Moriah and Westport Townships Essex Co. N. Y., with notes on the iron mines. 38p. 7pl. 2 maps Sep. 1895. 10c.
- 15 (EG6) Merrill, F: J. H. Mineral Resources of New York. 224p. 2 maps. Sep. 1895. 40c.

Volume 4

- 16 (A1) Beauchamp, W: M. Aboriginal Chipped Stone Implements of New York. 86p. 23pl. Oct. 1897. 25c.
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- 18 (A2) Beauchamp, W: M. Polished Stone Articles used by the New York Aborigines. 104p. 35pl. Nov. 1897. 25c.

- 19 (G₂) Merrill, F. J. H. Guide to the Study of the Geological Collections of the New York State Museum. 162p. 119pl. map. Nov. 1898. 40c.

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 25 (B₃) Peck, C. H. Report of the State Botanist 1898. 76p. 5pl. Oct. 1899. *Out of print.*

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 — The Water Biscuit of Squaw Island, Canandaigua Lake, N. Y.

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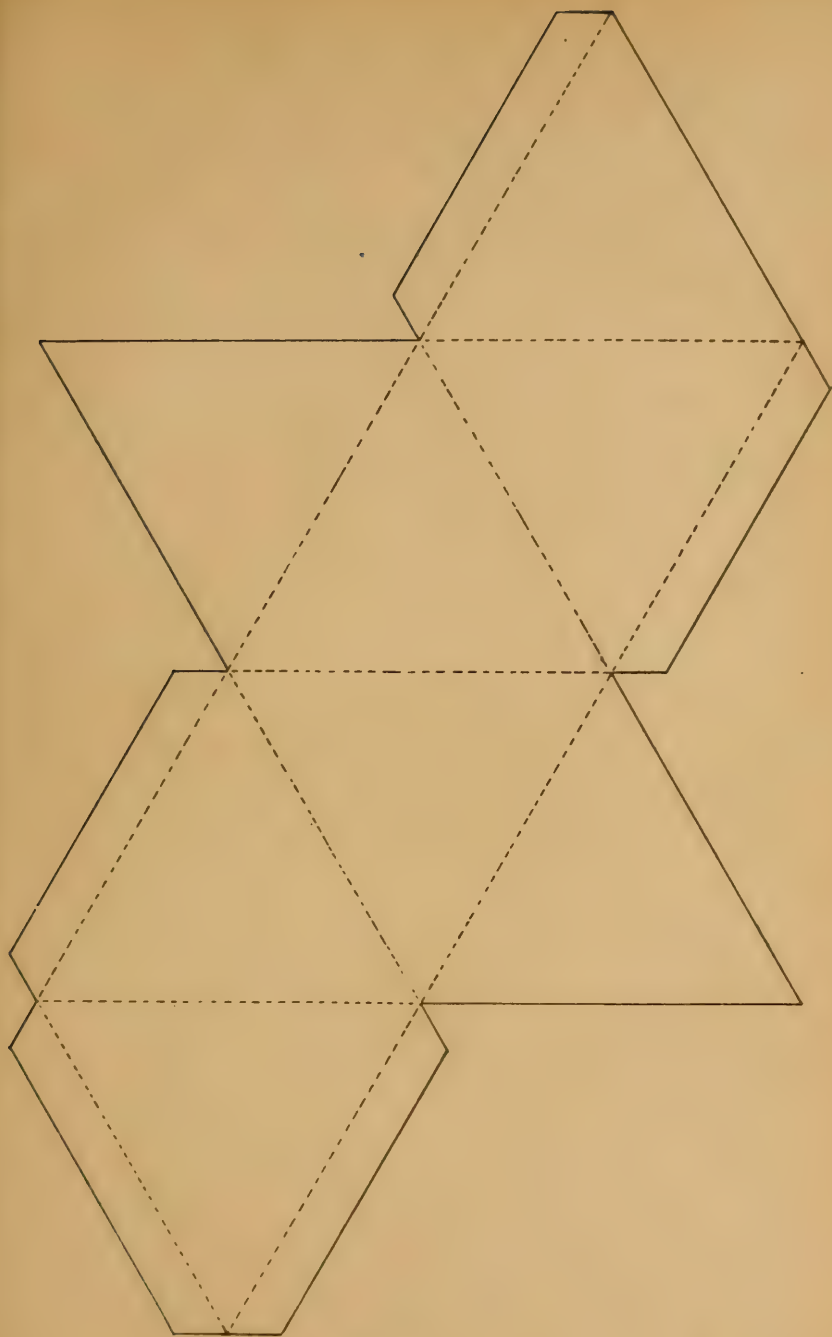
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 Eckel, E. C. Serpents of Northeastern United States.
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- 57 (E15) Felt, E. P. Elm Leaf Beetle in New York State. 46p. il. 8pl. Aug. 1902. 15c.
- 58 (M2) Whitlock, H. P. Guide to the Mineralogic Collections of the New York State Museum. 150p. il. 39 pl. 11 models. Sep. 1902. 40c.
 Merrill, F: J. H. Directory of Natural History Museums in United States and Canada. *In press.*
 Bean, T. H. Catalogue of the Fishes of New York. *In press.*
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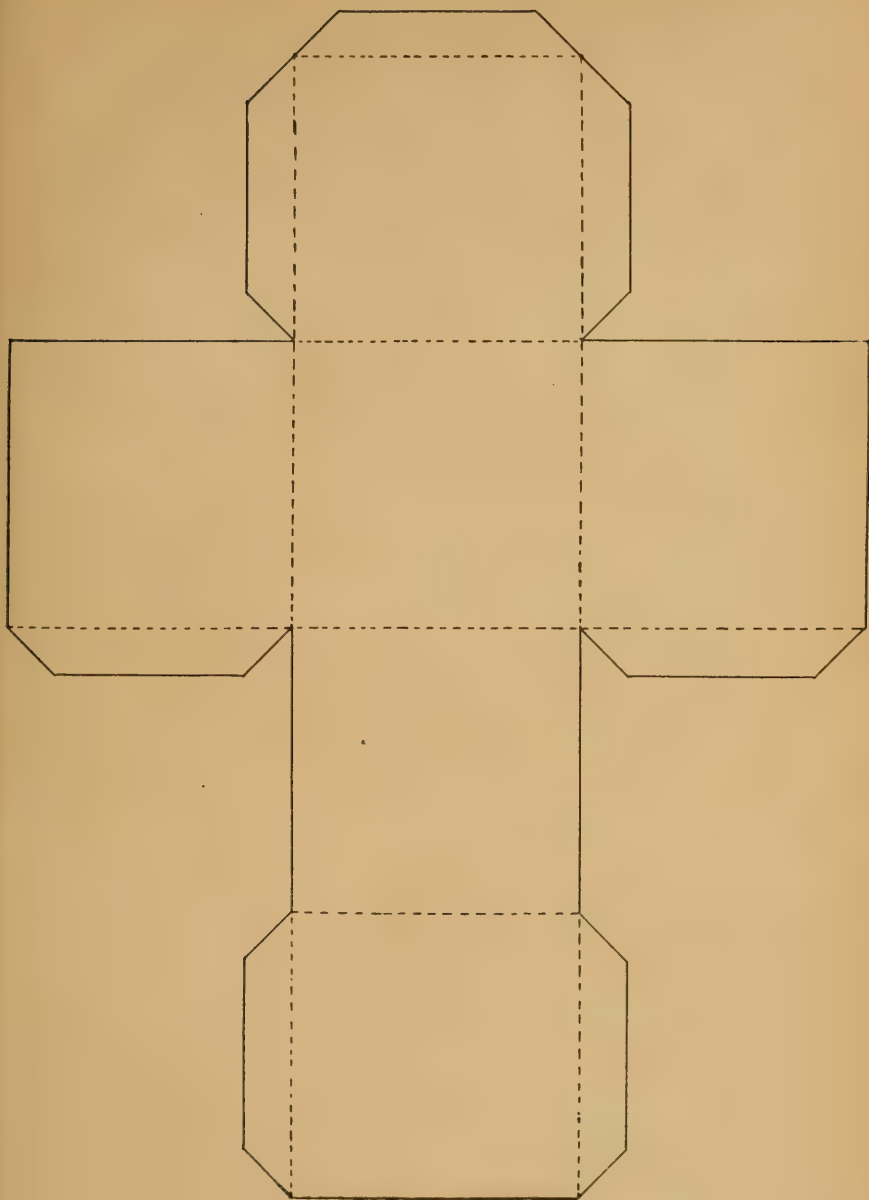
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Fold dotted lines.

Join with paste or mucilage.

Model 1

Octahedron



Model 2

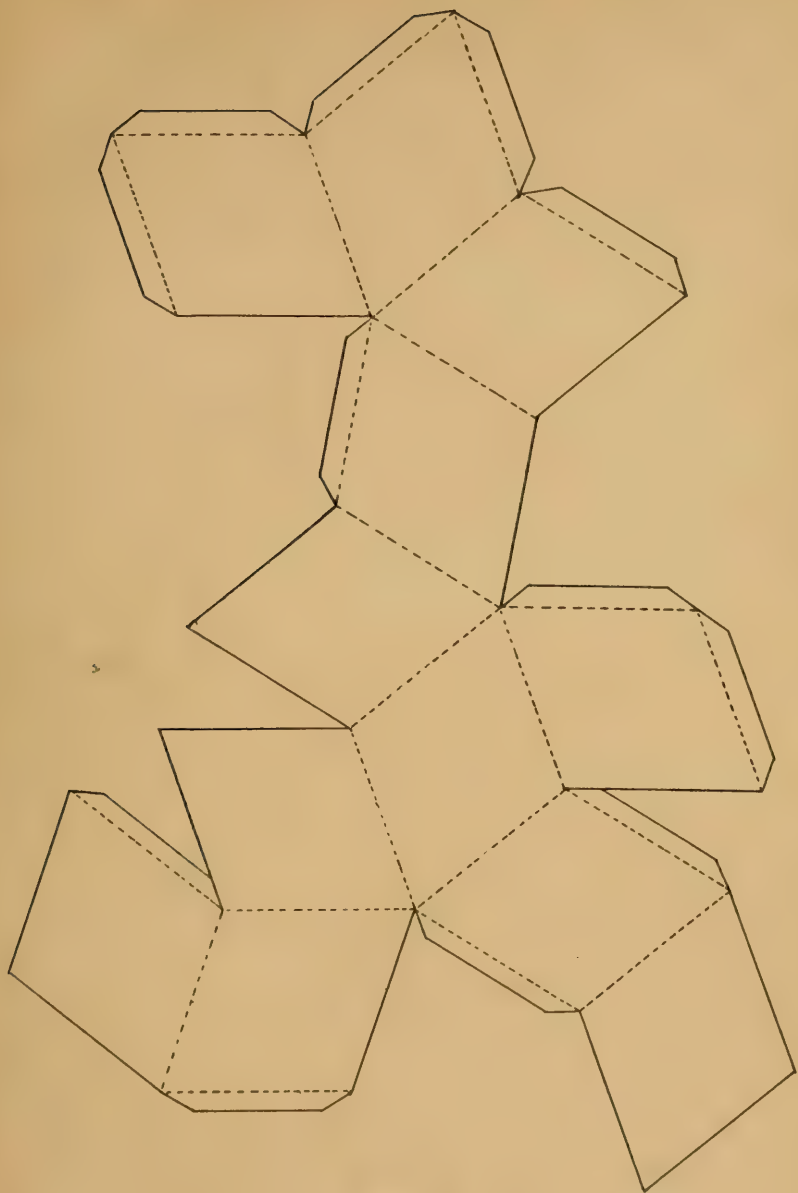
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Model 2

Cube



Model 3

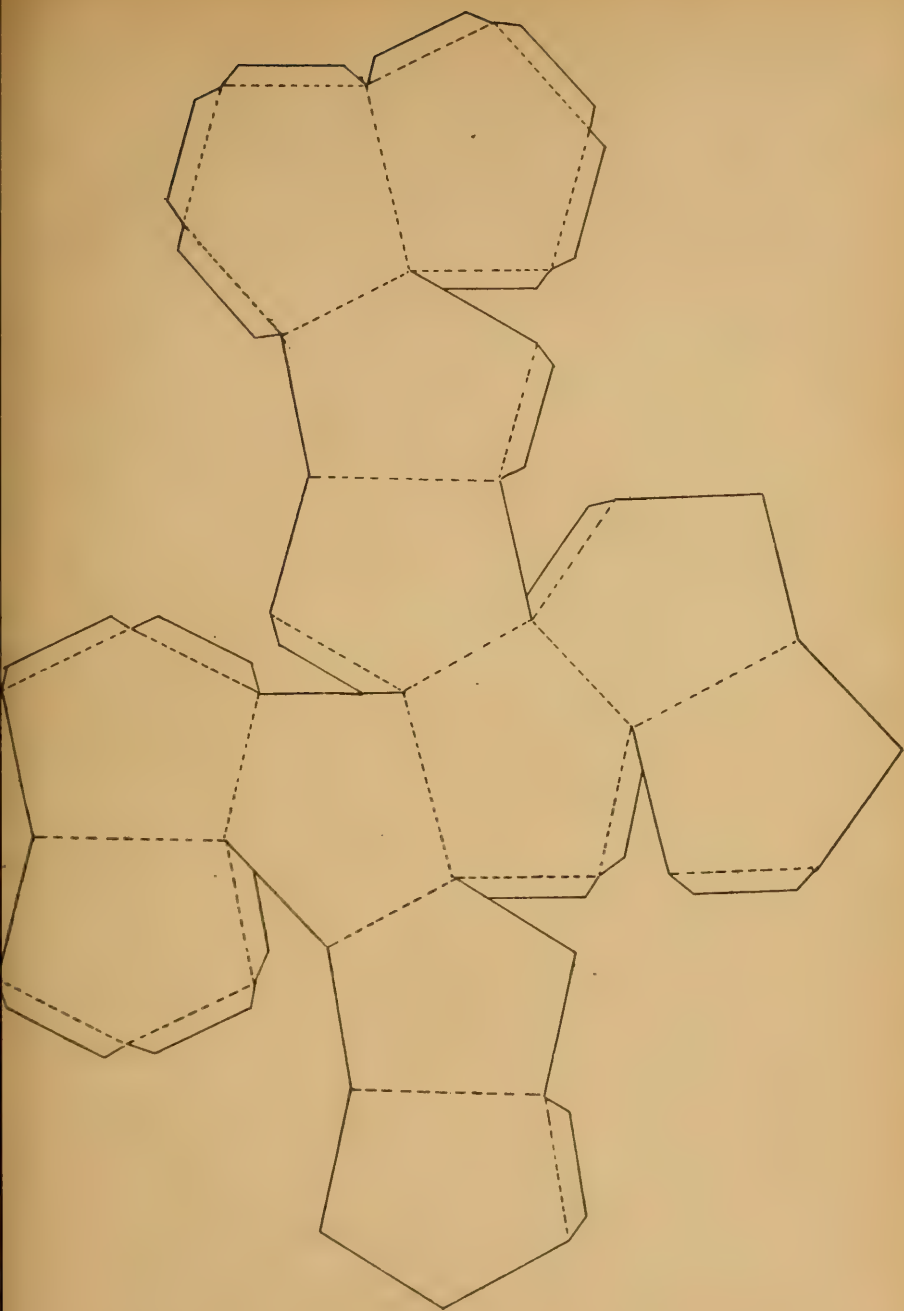
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Model 3

Dodecahedron



Model 4

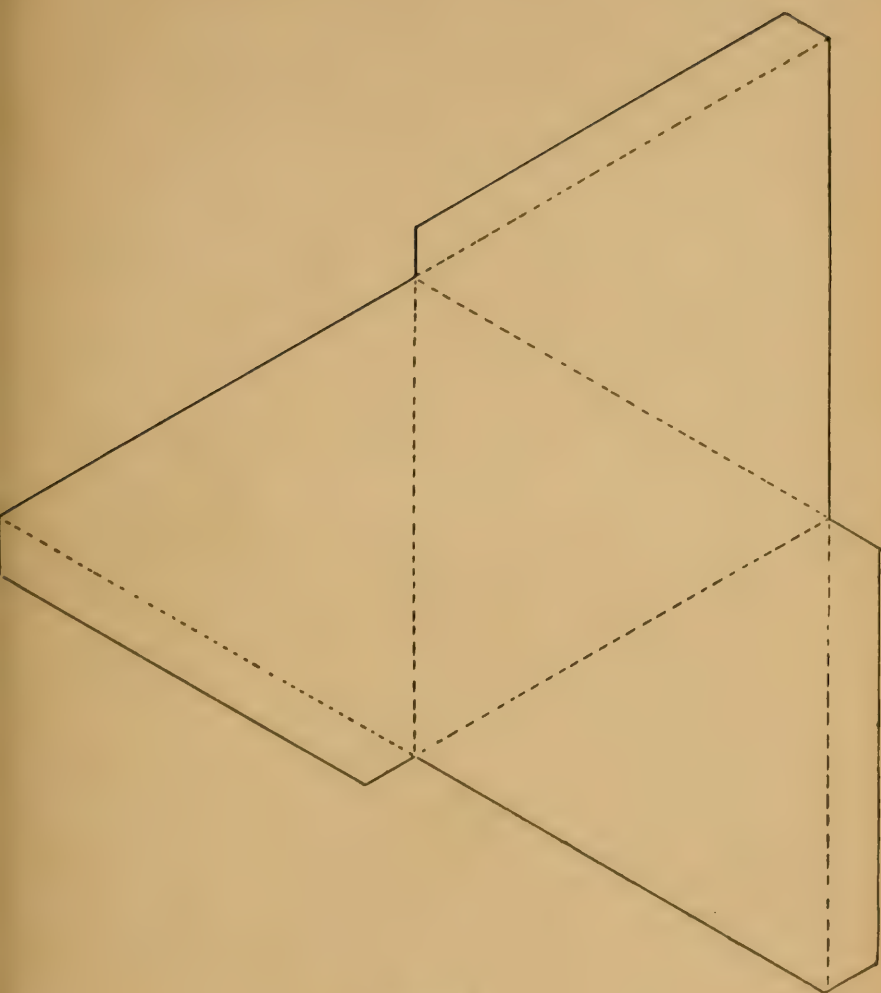
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Model 4

Pyritohedron



Model 5

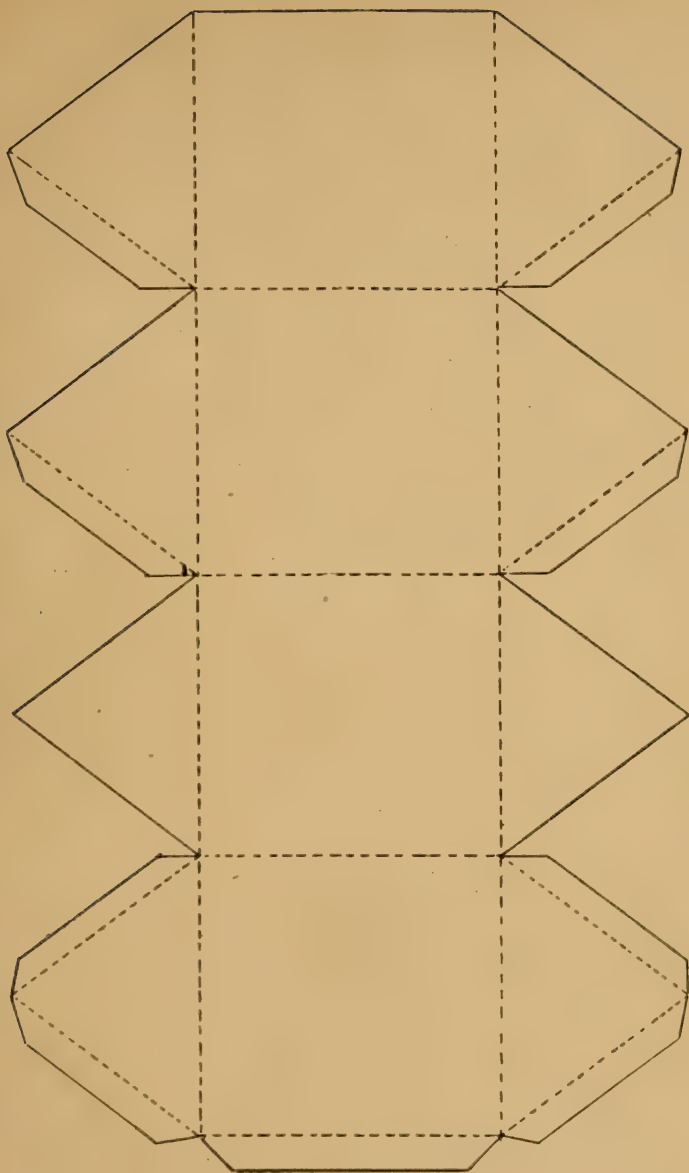
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Model 5

Tetrahedron



Model 6

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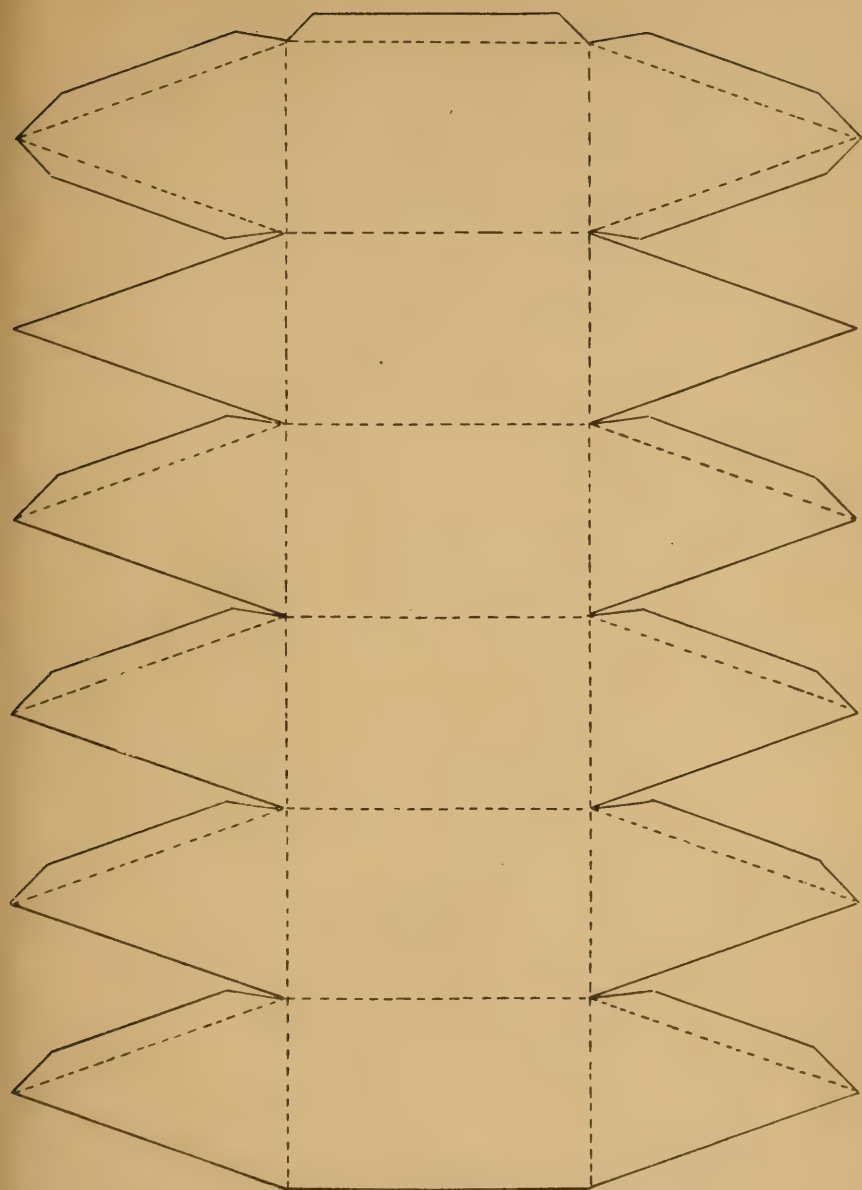
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Pyramid

Model 6

Prism

Pyramid



Model 7

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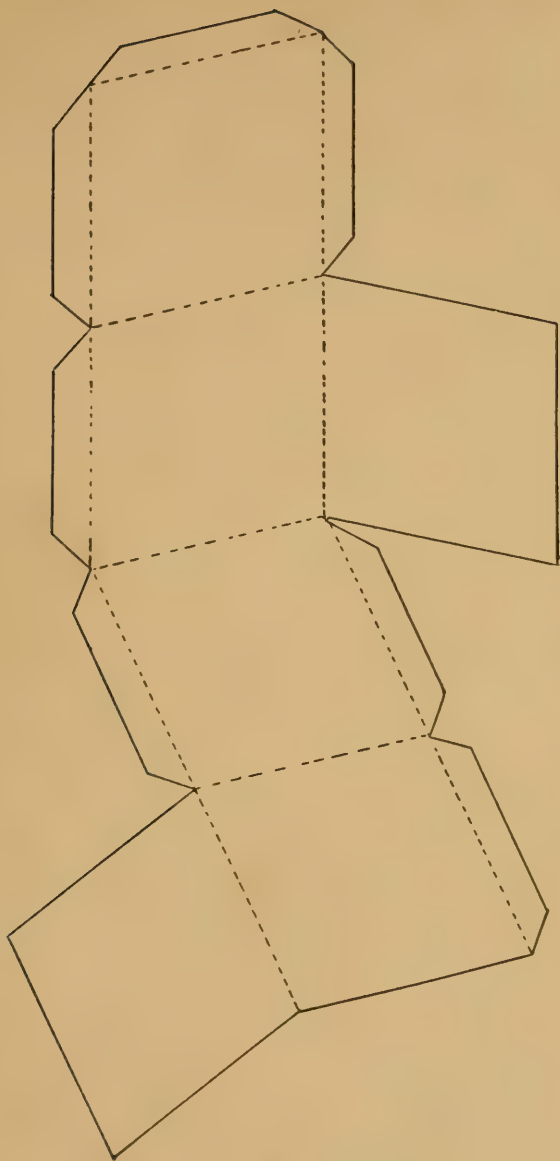
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Pyramid

Prism

Model 7

Pyramid



Model 8

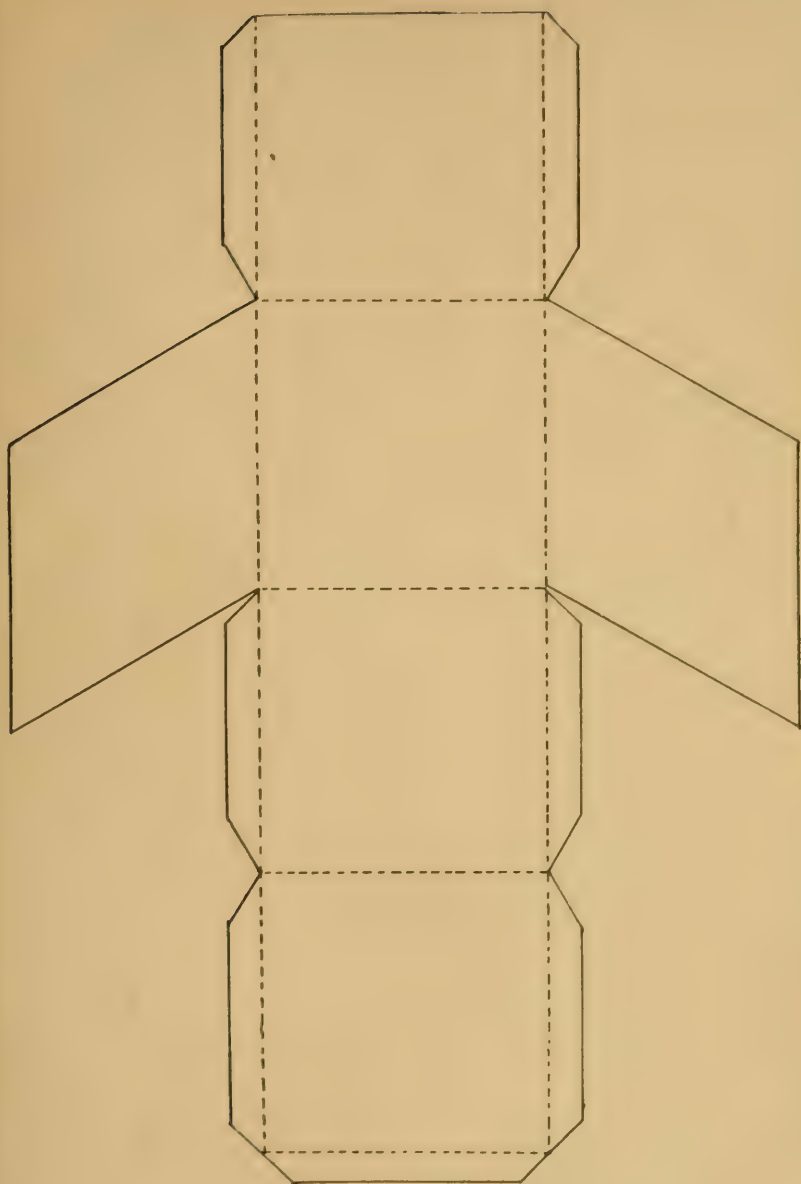
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Model 8

Rhombohedron



Model 9

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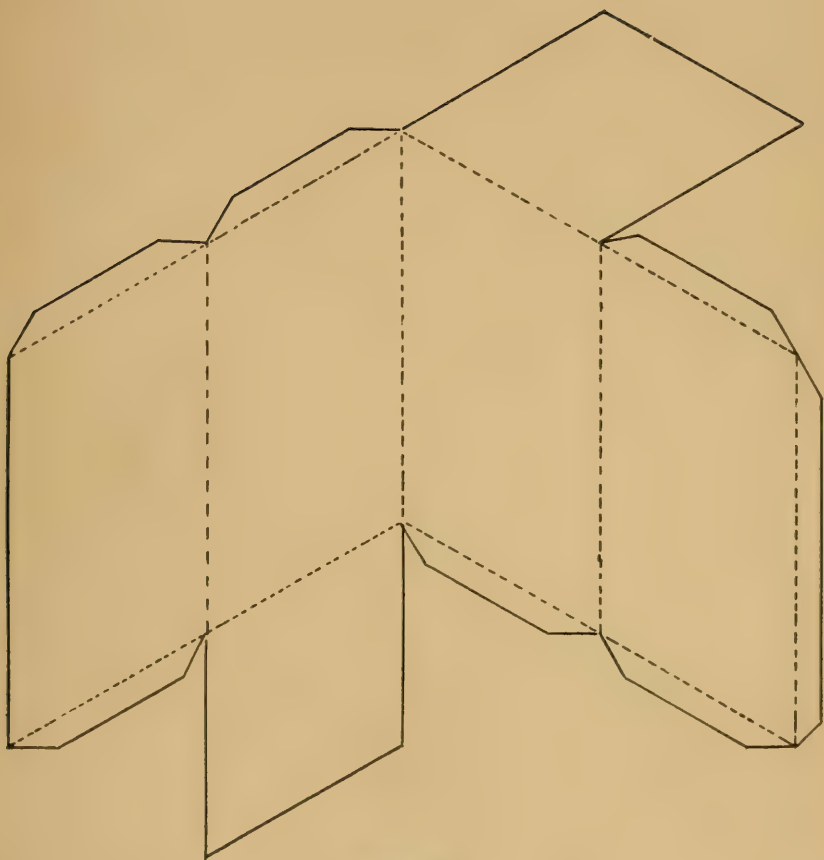
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Basal pinacoid

Model 9

Prism

Basal pinacoid



Model 10

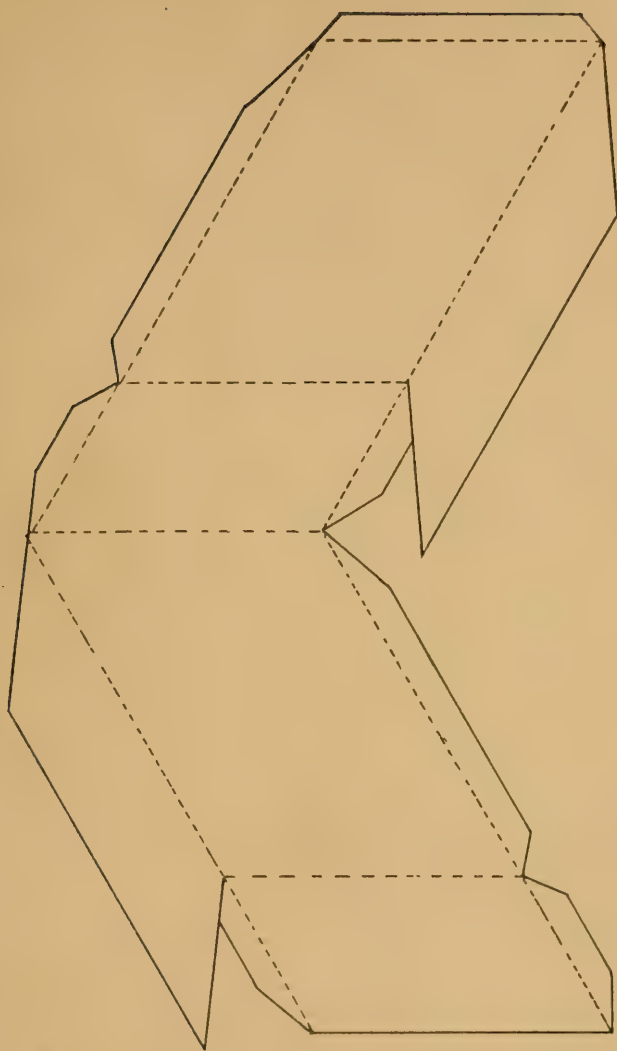
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Fold dotted lines.
Join with paste or mucilage.

Basal pinacoid

Prism

Model 10

Basal pinacoid



Model 11

Cut out solid lines.

Fold dotted lines.

Join with paste or mucilage.

Pinacoid

Pinacoid

Model 11

Pinacoid

MUSEUM PUBLICATIONS (concluded)

Museum memoirs 1889-date. Q.

- 1 Beecher, C. E. & Clarke, J. M. Development of some Silurian Brachiopoda. 96p. 8pl. Oct. 1889. *Out of print.*
- 2 Hall, James & Clarke, J. M. Paleozoic Reticulate Sponges. 35op. il. 7opl. Oct. 1899. \$1, cloth.
- 3 Clarke, J. M. The Oriskany Fauna of Becraft Mountain, Columbia Co. N. Y. 128p. 9pl. Oct. 1900. 80c.
- 4 Peck, C. H. N. Y. Edible Fungi, 1895-99. 106p. 25pl. Nov. 1900. 75c. This includes revised descriptions and illustrations of fungi reported in the 49th, 51st and 52d reports of the state botanist.
- 5 Clarke, J. M. & Ruedemann, Rudolf. The Guelph Formation and Fauna of New York State. *In preparation.*
- 6 Clarke, J. M. The Naples Fauna in Western New York. *In preparation.*

Natural history of New York. 30v. il. pl. maps. Q. Albany 1842-94.

- DIVISION 1 ZOOLOGY.** De Kay, James E. Zoology of New York; or, The New York Fauna; comprising detailed descriptions of all the animals hitherto observed within the State of New York with brief notices of those occasionally found near its borders, and accompanied by appropriate illustrations. 5v. il. pl. maps. sq. Q. Albany 1842-44. *Out of print.*
Historical introduction to the series by Gov. W. H. Seward. 178p.
- DIVISION 2 BOTANY.** Torrey, John. Flora of the State of New York; comprising full descriptions of all the indigenous and naturalized plants hitherto discovered in the State, with remarks on their economical and medical properties. 2v. il. pl. sq. Q. Albany 1843. *Out of print.*
- DIVISION 3 MINERALOGY.** Beck, Lewis C. Mineralogy of New York; comprising detailed descriptions of the minerals hitherto found in the State of New York, and notices of their uses in the arts and agriculture. il. pl. sq. Q. Albany 1842. *Out of print.*
- DIVISION 4 GEOLOGY.** Mather, W. W.; Emmons, Ebenezer; Vanuxem, Lardner & Hall, James. Geology of New York. 4v. il. pl. sq. Q. Albany 1842-43. *Out of print.*
- DIVISION 5 AGRICULTURE.** Emmons, Ebenezer. Agriculture of New York; comprising an account of the classification, composition and distribution of the soils and rocks and the natural waters of the different geological formations, together with a condensed view of the meteorology and agricultural productions of the State. 5v. il. pl. sq. Q. Albany 1846-54. *Out of print.*
- DIVISION 6 PALEONTOLOGY.** Hall, James. Paleontology of New York. 8v. il. pl. sq. Q. Albany 1847-94. *Bound in cloth.*

Museum handbooks 1893-date. 7½x12½ cm.

In quantities, 1 cent for each 16 pages or less. Single copies postpaid as below.

H5 New York State Museum. 14p. il. 3c.

Outlines history and work of the museum; with list of staff and scientific publications, 1893.

H13 Paleontology. 8p. 2c.

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H15 Guide to Excursions in the Fossiliferous Rocks of New York. 12op. 8c.

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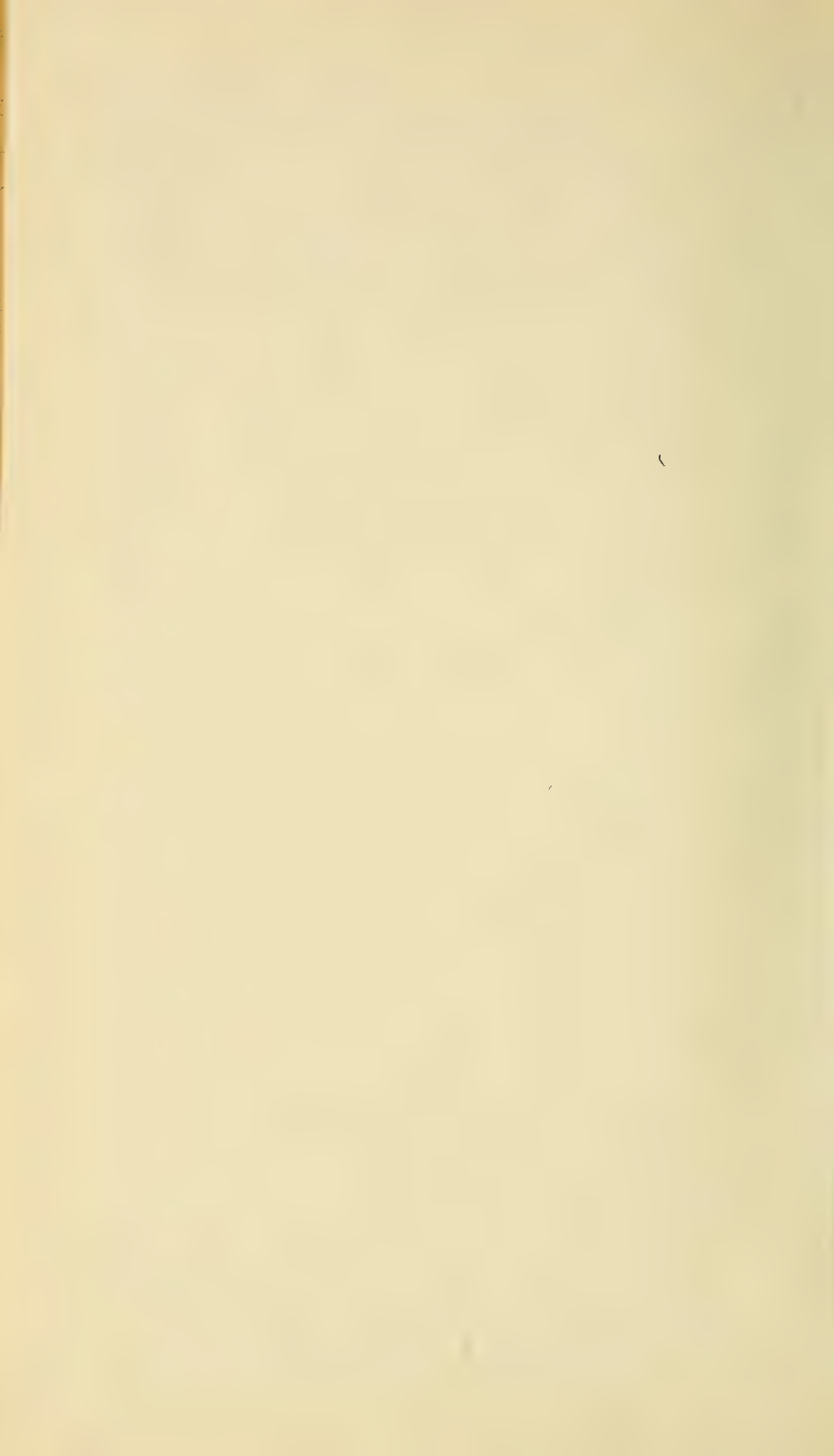
H16 Entomology. 8p. Out of print.**H17 Geology. In preparation.****Maps. Merrill, F. J. H. Economic and Geologic Map of the State of New York. 59x67 cm. 1894. Scale 14 miles to 1 inch. Out of print.**

New edition in preparation.

Printed also with Museum bulletin 15 and the 48th museum report, v. 1.

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The lower Hudson sheet, geologically colored, comprises Rockland, Orange, Dutchess, Putnam, Westchester, New York, Richmond, Kings, Queens and Nassau counties, and parts of Sullivan, Ulster and Suffolk counties; also north-eastern New Jersey and part of western Connecticut.







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